FINAL
FEASIBILITY STUDY

INVESTIGATION AREA H1
Mare Island, Vallejo, California

Prepared for

DEPARTMENT OF TOXIC SUBSTANCES CONTROL
Berkeley, California

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40 CFR	Code of Federal Regulations, Title 40
27 CCR	California Code of Regulations, Title 27
95UCL	95 Percent Upper Confidence Limit
AM	Action Memorandum
amsl	above mean sea level
Aqua Terra	Aqua Terra Technologies
ARAR	Applicable or Relevant and Appropriate Requirement
BAF	Bioaccumulation Factor
bgs	below ground surface
BW	Body Weight
CCL	compacted clay layer
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cm/s	centimeters per second
COC	Chemical of Concern
COEC	Chemical of Ecological Concern
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CPT	Cone Penetrometer Testing
DAF	Dilution/Attenuation Factor
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichchloroethene
DDT	Dichlorodiphenyltrichloroethane
DOD	United States Department of Defense
DON	United States Department of the Navy
DTSC	California Department of Toxic Substances Control

DWBZ	Deep Water Bearing Zone
E&E	Ecology and Environment, Inc.
EFA WEST	Naval Facilities Engineering Command, Engineering Field Activity West
EPA	United States Environmental Protection Agency
ERA	Ecological Risk Assessment
ESA	Endangered Species Act
ESCA	Environmental Services Cooperative Agreement
FIR	Food Ingestion Rate
FS	Feasibility Study
GCL	Geo-Synthetic Membrane Liner
GRA	General Response Action
HASP	Health and Safety Plan
HDPE	High-Density Polyethylene
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IA-H1	Investigation Area H1
IR	Installation Restoration
IRAP	Interim Remedial Action Plan
IRP	Installation Restoration Program
IT	International Technology Corporation
IW	Industrial Wastewater
IWBZ	Intermediate Water Bearing Zone
IWTP	Industrial Wastewater Treatment Plant

kg	kilogram
MBTA	Migratory Bird Treaty Act
MC	Munitions Constituents
MEC	Munitions and Explosives of Concern
MINS	Mare Island Naval Shipyard
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mm	millimeter
NAD	Naval Ammunition Depot
NAPL	Non-Aqueous Phase Liquid
NCP	National Contingency Plan
NMOC	Non-Methane Organic Compound
O&M	Operations and Maintenance
OE	Ordnance and Explosives
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
PRC	PRC Environmental Management, Inc.
PRG	Preliminary Remediation Goal
RAB	Restoration Advisory Board
RAD	Radiological
RAO	Remedial Action Objective
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act of 1976
RI	Remedial Investigation

RME	Reasonable Maximum Exposure
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act of 1986
SSCG	Site-Specific Clean up Goal
SSTP	Sanitary Sewage Treatment Plant
SUF	Site Use Factor
SVOC	Semi-Volatile Organic Compound
SWBZ	Shallow Water Bearing Zone
TBC	To Be Considered
TPH	Total Petroleum Hydrocarbons
TPH-d	Total Petroleum Hydrocarbons as Diesel
TPH-g	Total Petroleum Hydrocarbons as Gasoline
TPH-m	Total Petroleum Hydrocarbons as Motor Oil
TRV	Toxicity Reference Value
TtEMI	Tetra Tech EM, Inc.
UCL	Upper Confidence Limit
USFWS	United States Fish and Wildlife Service
VOC	Volatile Organic Compound
VSFCD	Vallejo Sanitation and Flood Control District
WESTON	Weston Solutions, Inc.
WMA	Western Magazine Area

EXECUTIVE SUMMARY

Weston Solutions, Inc. (WESTON) prepared this Feasibility Study (FS) for Investigation Area H1 (IA-H1) at the former Mare Island Naval Shipyard (MINS) in Vallejo, California. This document is based upon the findings of the Final Remedial Investigation (RI) for IA-H1 (WESTON, 2005a) and focuses on remediation alternatives that protect human health and the environment, including groundwater resources.

This FS discusses remedial alternatives for three areas within IA-H1: the Containment Area inside the existing groundwater Containment Barrier, the Upland Areas outside the Containment Barrier, and the Non-Tidal Wetland Areas outside the Containment Barrier.

The FS development process consists of the following steps:

- Development of remedial action objectives (RAOs) that specify the contaminants of concern, exposure pathways, and remediation goals and permit a range of alternatives to be developed. RAOs are developed on the basis of applicable or relevant and appropriate requirements (ARARs).
- Development of general response actions (GRAs) that define contaminant removal, disposal or other actions, individually or in combination, that can be taken to satisfy the RAOs.
- Identification of proposed removal volumes or areas to which the GRAs apply.
- Further define GRAs to specify types of remedial technologies.
- Identification and screening of remedial technologies for each GRA to eliminate technologies that cannot be technically or cost-effectively implemented.
- Identifying and screening process options for each remedial technology and assembling process options into alternatives, screening the alternatives, and evaluating retained alternatives.

Remedial Action Objectives

RAOs were developed to protect human health and the environment and include the chemicals of ecological concern (COECs), chemicals of concern (COCs) for human health, the exposure route(s), the exposure receptor(s), and the acceptable contaminant level.

Containment Area

The primary exposure pathways for landfill refuse and contaminated media are dermal contact, ingestion, and inhalation of compounds. Potential exposure at the interim status Resource Conservation and Recovery Act (RCRA) Landfill is limited by required cover maintenance. However, the non-RCRA areas, including the Facility Landfill and remaining portion of the Containment Area, could experience erosion, exposing refuse and contaminated media, thereby potentially enhancing risks of ingestion and inhalation of materials of concern. In addition, erosion could result in migration of contaminants off site. The general RAO for the Containment Area is to protect human and ecological receptors from exposure to landfill contamination by eliminating exposure pathways and contaminant migration.

Groundwater under the landfill is not suitable for human consumption and is, therefore, not a threat to drinking water; however, migration of the contaminated groundwater may have an adverse ecological effect. The RAO for groundwater is to minimize the effects of landfill contaminants on groundwater quality (through infiltration) and eliminate migration of contaminated groundwater to potential off-site ecological receptors.

The landfill gas investigations indicate that gas, including methane, carbon dioxide, and volatile organic compounds (VOCs), is being generated at the RCRA Landfill. Therefore, the general RAO for landfill gas is to protect human and ecological receptors by minimizing exposure pathways and gas migration.

Upland Areas outside the Containment Barrier

The soil RAOs for the Upland Areas outside the Containment Barrier are as follows:

- Reduce exposure via inhalation, dermal contact, and ingestion of site soil containing arsenic, lead, Aroclor-1260, and benzo(a)pyrene concentrations presenting an area-wide cancer risk estimate greater than $1x10^{-5}$ (without the contribution of the ambient/background arsenic) or noncarcinogenic adverse health effects resulting in a hazard index (HI) greater than 1.
- Reduce exposure to COECs present in the soil posing potential risk to the gray fox (lead and selenium), the northern harrier (lead), and the western meadowlark (cadmium, chromium, copper, lead, mercury, selenium, dichlorodiphenyldichloroethane [DDD], and dichlorodiphenyltrichloroethane [DDT]).

- Reduce migration of contaminants in surface soils towards the sediment and surface water of the Non-Tidal Wetland Areas.

- The groundwater RAO for the Upland Areas outside the Containment Barrier is to reduce downward or lateral migration of soil contaminants to the shallow water-bearing zone (SWBZ).

Non-Tidal Wetland Areas outside the Containment Barrier

The soil/sediment RAOs for the Non-Tidal Wetland Areas outside the Containment Barrier are as follows:

- Reduce exposure via inhalation, dermal contact, and ingestion of site soil with arsenic, lead, Aroclor-1260, and carcinogenic polynuclear aromatic hydrocarbon (PAH) concentrations presenting an area-wide cancer risk greater than $1x10^{-5}$ (without the ambient/background arsenic contribution) or noncarcinogenic adverse health effects resulting in a HI greater than 1.
- Reduce exposure to COECs in the sediment posing immediate or significant risk to the killdeer (chromium, copper, lead, manganese, mercury, nickel, selenium, zinc, and total polychlorinated biphenyls [PCBs]) and potential risk to the great blue heron (copper, lead, mercury, and total PCBs), the mallard (lead), and the salt marsh harvest mouse (antimony, copper, lead, manganese, mercury, nickel, selenium, vanadium, zinc, and total PCBs).

Remedial Action Alternatives

Based on the evaluation of remedial technologies and process options with respect to effectiveness, implementablity, and cost criteria (Section 3), and the development of alternatives using the process options evaluated and site-specific conditions (Section 4), the following alternatives were identified for detailed analysis for the IA-H1 area:

Containment Area

- Alternative 1─No Action
- Alternative 2A─Variable Multilayer Cap, Institutional Controls, Groundwater Containment, and Landfill Gas Monitoring
- Alternative 2B─Uniform RCRA Cap, Institutional Controls, Groundwater Containment, and Landfill Gas Monitoring
- Alternative 3─Removal and Disposal

Upland Areas outside the Containment Barrier

- Alternative 1─No Action
- Alternative 2─Institutional Controls, Hot Spot Removal (Ecological Hazard Quotient [HQ]=10), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 3─Institutional Controls, Hot Spot Removal (HQ=5), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 4─Institutional Controls, Hot Spot Removal (HQ=3), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 5─Complete Debris Excavation and Groundwater Monitoring

Non-Tidal Wetland Areas outside the Containment Barrier

- Alternative 1─No Action
- Alternative 2─Institutional Controls, Hot Spot Removal (HQ=10), and Monitoring
- Alternative 3─Institutional Controls, Hot Spot Removal (HQ=5), and Monitoring
- Alternative 4─Institutional Controls, Hot Spot Removal (HQ=3), and Monitoring
- Alternative 5─Institutional Controls, Hot Spot Removal (HQ=1), and Monitoring

Alternative Analysis

A detailed analysis was conducted to provide an assessment and to profile each alternative against the nine evaluation criteria in the National Contingency Plan (NCP). The first two evaluation criteria are as follows: overall protection of human health and the environment and compliance with ARARs (or waiving of ARARs where appropriate). These evaluation criteria are thresholds that must be met, i.e., threshold criteria. The next five criteria (balancing criteria) are the primary basis for the detailed analysis (United States Environmental Protection Agency [EPA] 1988). The last two NCP criteria, known as modifying criteria, will be considered by the reviewing agencies after the Record of Decision has been released to the public for review and comment. The review and comment process will follow the NCP, EPA guidance, and State of California procedures for preparing Remedial Action Plans.

The nine evaluation criteria are as follows:

Threshold Criteria

1. Overall protection of human health and the environment
2. Compliance with ARARs

Balancing Criteria

1. Long-term effectiveness and permanence
2. Reduction in toxicity, mobility, or volume
3. Short-term effectiveness
4. Implementability
5. Cost

Modifying Criteria

1. State acceptance
2. Community acceptance

Summary of Evaluation of Alternatives

Containment Area

Alternative 1 does not satisfy the two threshold criteria and, therefore, cannot be selected. Alternatives 2A, 2B (variable and uniform RCRA cap, respectively) and 3 (removal and off-site disposal) satisfy the threshold criteria. Alternative 2A and 2B are similar based on short-term effectiveness and implementability, but Alternative 2B is more expensive by $2,310,000. All cost estimates include a 25 percent contingency factor. Alternative 2B provides for a geosynthetic clay liner (GCL) layer under a geomembrane over the entire Containment Area (72 acres), whereas Alternative 2A includes this GCL layer only under the RCRA interim status areas, and where elevated methane levels were detected or can be expected (i.e. Facility Landfill), which includes 32 acres within the Containment Area. These alternatives both depend on continuing maintenance of the landfill cap for long-term effectiveness. Alternative 3 is much more difficult to implement and has more severe short-term impacts due to the large amount of material required to be excavated, moved (approximately 50,000 truckloads), and disposed. A fence will be installed, restricting access to the Containment Area.

Alternative 2A is the highest ranking remedy for the Containment Area with a total present worth cost of $31,300,000. Included in this amount is $2,390,000 for the containment barrier, which is now in place. This alternative also satisfies the threshold criteria while balancing long-term and short-term effectiveness at a reasonable cost.

Upland Areas outside the Containment Barrier

Alternative 1 does not satisfy the two threshold criteria and, therefore, cannot be selected. Alternatives 2, 3, 4 and 5 do satisfy these criteria. Alternatives 2, 3 and 4 provide the greatest protection to the environment, and are preferred based on short-term and long-term effectiveness, implementability, and cost. There is no significant difference in human health risk reduction between Alternatives 2, 3, and 4. Very little ecological risk reduction is realized at the higher levels of hot spot removal and the two-foot soil cover provides a barrier to any remaining risk. Alternative 5 is much more difficult to implement and has more severe short-term impacts due to the large amount of material required to be excavated and a much higher cost of relative cost of $19,181,000.

Alternative 4 is ranked as the best remedy for the Upland Areas outside the Containment Barrier with a total cost of $3,160,000. This alternative satisfies the threshold criteria while balancing long-term and short-term effectiveness at a reasonable cost.

Non-Tidal Wetland Areas outside the Containment Barrier

Alternative 1 does not satisfy the two threshold criteria and, therefore, cannot be selected. Alternatives 2, 3, 4 and 5 do satisfy these criteria. Alternative 5 provides the greatest protection to the environment due to the HQ of 1 applied for the resident endangered species, the salt marsh harvest mouse, and has the best ranking based on short-term and long-term effectiveness, implementability, and cost.

Alternative 5 has a total cost of $365,000. This alternative satisfies the threshold criteria while balancing long-term and short-term effectiveness at a reasonable cost.

1. INTRODUCTION

In accordance with the Mare Island Remediation Agreement between the City of Vallejo and Weston Solutions, Inc. (WESTON) and the Environmental Services Cooperative Agreement between the United States Department of the Navy (DON) and the City of Vallejo, WESTON is submitting this Draft Final Feasibility Study (FS) for Investigation Area H1 (IA-H1) of the Mare Island Naval Shipyard (MINS). This document is based upon the findings of the Final Remedial Investigation (RI) for IA-H1, Mare Island, Vallejo, California (WESTON, 2005a).

1.1 PURPOSE AND ORGANIZATION OF REPORT

As described in the United States Environmental Protection Agency (EPA) Guidance for Conducting RIs and FSs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Interim Final (EPA, 1988), the purpose of the FS is to identify remedial action objectives; identify potential treatment, resource recovery, and containment technologies that will satisfy these objectives; screen the technologies based on their effectiveness, implementability, and cost; and assemble the technologies and their associated containment or disposal requirements into alternatives for the contaminated media at the site or for the operable unit. A range of remedial alternatives has been developed and evaluated in this FS report that minimize the potential for human exposure to contaminated material and the effects of contaminants on the environment, and are feasible, implementable, and cost effective. This report evaluates these remedial alternatives for the three exposure areas within IA-H1: the Containment Area inside the existing groundwater Containment Barrier, the Upland Areas outside the Containment Barrier, and the Non-Tidal Wetland Areas outside the Containment Barrier.

These three areas contain subareas based on historical IA-H1 use and are shown in Figure 1-1. The Containment Area consists of the Landfill Subarea, the Sludge Treatment/Surface Impoundment Subarea, the Waste Disposal Sump/Lead Oxide Storage and Disposal Subarea, Wetland X, and portions of the West Subarea and Northwest Dump Road Subarea. The Upland Areas consist of the Sanitary Sewage Treatment Plant Subarea, the Demolition Debris Subarea, the Fire-Fighting Training Subarea, and portions of the West Subarea, the Northwest Dump

Road Subarea, and the Solid Waste Disposal/Lead Oxide Storage and Disposal Subarea. The Non-Tidal Wetland Areas consist of the North Wetlands Subarea (Wetlands A and D), the South Dredge Pond Subarea (Wetlands B and C), the Northwest Dump Road Wetland, and the Former Dredge Pond 1. Historical operations and disposal activities at each of these subareas is discussed in Section 2 of this FS.

The Containment Area is surrounded by a groundwater Containment Barrier and extraction trench, as implemented during the Interim Remedial Action in September 2004 (WESTON, 2004b). Applying EPA presumptive remedy guidance for municipal and military landfills (EPA, 1993 and 1996) to the subareas of the Containment Area described above resulted in the containment presumptive remedy being implemented to streamline the FS process. The Waste Disposal Sump/Lead Oxide Storage and Disposal Subarea is not considered a municipal landfill by practice; however, it still contains a volume of contaminated material that would be impractical to treat. Therefore, the Engineering Evaluation/Cost Analysis (WESTON, 2003a) concluded that containment was the most cost-effective alternative to achieve the Removal Action Cleanup Goals for this subarea and is consistent with the presumptive remedy for landfills.

This FS was prepared in accordance with the EPA guidance document (EPA, 1988) and the National Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] Part 300. The EPA guidance document provides an approach to identify and analyze remedial alternatives. Remedies can include (1) natural attenuation; (2) destruction of contaminants or a reduction in their volume, toxicity, or mobility; and (3) reduction of exposure pathways. A “No Action” alternative or institutional controls may be selected if they are protective of human health and the environment. The FS process consists of the following steps:

- Develop remedial action objectives (RAOs) that specify the contaminants of concern, exposure pathways, and remediation goals that permit a range of alternatives to be developed. RAOs are developed on the basis of chemical-specific applicable or relevant and appropriate requirements (ARARs)
- Develop general response actions (GRAs) that define containment, removal, disposal, or other actions that can be taken to satisfy the RAOs
- Identify and screen remedial technologies for each GRA to eliminate technologies that cannot be technically or cost-effectively implemented

- Combine remedial technologies to develop a set of remedial alternatives
- Evaluate the remedial alternatives and select the most favorable alternatives for detailed analysis
- Present a detailed analysis of the most favorable alternatives

This FS contains seven sections and three appendices. Section 1 describes the FS purpose and scope. Section 2 describes the site history and develops a site profile, including a summary of past site investigation activities, site geology and hydrogeology, the nature and extent of contamination, and contaminant fate and transport. Section 2 also summarizes the human health risk assessment (HHRA) and ecological risk assessment (ERA) and discusses the basis for ARARs. Section 3 develops the RAOs, presents GRAs, and identifies and screens technologies and process options. Section 4 discusses the development of remedial alternatives, and Section 5 analyzes these alternatives. Section 6 includes a comparative analysis of alternatives. Section 7 includes references cited in this FS.

2. BACKGROUND INFORMATION

2.1 SITE LOCATION AND HISTORY

The Mare Island peninsula is located in Solano County, California, approximately 25 miles northeast of San Francisco (Figure 2-1). Mare Island is bordered by San Pablo Bay to the west, Carquinez Strait to the south, and Highway 37 to the north. The Napa River (Mare Island Strait) separates the island from the mainland and the City of Vallejo to the east. The main entrance to Mare Island is a causeway that spans Mare Island Strait, connecting the island to the City of Vallejo at Tennessee Street. A second access is located at the northern end of the island, where Railroad and Walnut Avenues connect to Highway 37. Mare Island is within the incorporated boundaries of the City of Vallejo.

Investigation Area H1 (IA-H1) shown in Figure 2-2, occupies approximately 230 acres. Its elevation varies from 6 feet above mean sea level (amsl) in the wetland and dredge pond areas to 23 feet amsl on the berms. The exception to this elevation range is the Resource Conservation and Recovery Act (RCRA)/ Facility Landfill, where the top of the land surface is 42 feet amsl. IA-H1 is bounded by dredge ponds to the north, west, and south, and by uplands and seasonal wetlands to the east. IA-H1 is currently isolated from the rest of Mare Island by a locked gate and fence located at the Dump Road entrance to IA-H1.

The following discussion on the historical development of Mare Island is based on information presented in a historical survey of the shipyard (Mighetto and Youngmeister, 1986) and an archeological resources inventory (Archeological Resource Service, 1986), unless noted otherwise.

Mare Island was the first naval station established on the Pacific Coast. The United States Department of the Navy (DON) purchased 956 acres of Mare Island in 1853 and commenced shipbuilding operations on 16 September 1854. The subsections that follow describe the development of the infrastructure of the island and the primary historical land uses and activities. These activities included shipbuilding, ship repair, dredge and fill activities, manufacture and storage of munitions, and waste disposal.

2.1.1 Infrastructure

Mare Island was originally a true island off the shore of Vallejo, accessible only by boat. Ferries transported shipyard workers and supplies. The first crossing, constructed in 1919, was a wooden causeway with a drawbridge that connected Mare Island (at A Street) to Vallejo (at Tennessee Street). The existing concrete causeway (also with a drawbridge) that connects to Mare Island at G Street replaced this crossing in 1935.

In the late 19th century, roadways on the island were unpaved. Horses and carts were used to transport raw materials from the docks to the shops and finished products back to the ships. By the early 20th century, roads were being paved and railroad tracks were installed. When the concrete causeway was completed in 1935 with a railroad track to the mainland, trains became the primary mode of transportation for both workers and supplies.

When shipyard operations first began, every tool shop on the Mare Island Naval Shipyard (MINS) had its own source of heat and power. As the facilities expanded, the need for centralized power increased. Consequently, in 1918, the DON constructed a steam-driven power plant (Building 121) to supply the shipyard with both steam (for heat and industrial processes) and electrical power. To meet the rising demand for power in the late 1930s, an overhead, auxiliary power connection was established with Pacific Gas and Electric Company. Tall transmission towers were constructed on both sides of Mare Island Strait; this system is still the primary source of electrical power for Mare Island.

When the shipyard was being constructed during the latter half of the 19th century, fresh water was not plentiful on the island. The DON first established a reservoir in the hills on the southern portion of the island and constructed a variety of cisterns near the housing and industrial areas for storing water necessary for drinking and fighting fires. Some cisterns are still present in the historical portions of the shipyard. In 1898, a pipeline was installed from Vallejo to deliver fresh water. The reservoir was then used primarily for fire protection in the ordnance manufacturing and storage areas.

In 1928, when the first pump was installed in Building 121, a saltwater distribution system began delivering saltwater for fire protection and various shipyard needs (Metcalf and Eddy, Inc.,

1976). Additional pumps and piping were later installed to carry saltwater to the fire fighting training school within IA-H1, the ordnance manufacturing and storage areas, and other locations across the island.

The storm water collection system originally carried storm water runoff, sanitary sewage, and industrial wastewater (IW) to outfalls along Mare Island Strait. In the late 1950s, a sanitary sewer system was built to divert the sanitary waste to a new Sanitary Sewage Treatment Plant (SSTP) located in the western portion of Mare Island at the western end of Dump Road within IA-H1. Treated effluent from the plant was discharged into San Pablo Bay. New sewers were also installed in the 1950s to separate storm water and sanitary waste, preventing combined overflows to the strait.

An IW collection system pipeline and the Industrial Wastewater Treatment Plant (IWTP) were constructed in 1972. The IW collection system connected to industrial shops across Mare Island, conveying IW to the IWTP built adjacent to the SSTP within IA-H1. Treated effluent was discharged into San Pablo Bay until 1976, when this practice was prohibited. The treated effluent was then routed to the City of Vallejo wastewater treatment plant. Table 2-1 lists the source, amount, and type of liquid wastes discharged to the IWTP during its operation. The SSTP and IWTP aboveground structures were demolished by Weston Solutions, Inc. (WESTON) in 2002 and belowground structures were abandoned in place in 2004 and the area graded.

2.1.2 Ship Construction and Maintenance Activities

The primary ship construction and maintenance area of the shipyard was established along the northeast shore of the original island, adjacent to Mare Island Strait. Initially, this area was roughly bounded by A Street on the north, 11th Street on the south, and Railroad Avenue on the west. The shipyard area then expanded to cover an area roughly bounded by G Street to the north, Railroad Avenue to the west, and the Building 900 area to the south. A number of brick buildings constructed in the late 19th century are still present in the original shipyard area; this area has been designated a historic district. The entire shipyard has undergone vast transformations during years of operation as shipbuilding technologies advanced from wooden to steel construction and from wind power to nuclear propulsion. With these changes, the variety

and amount of industrial chemicals and oils used in construction and maintenance activities increased. Table 2-2 lists a number of chemical wastes generated by MINS that have the potential for moderate to high environmental impact.

The first permanent dry dock on the Pacific Coast was completed at Mare Island in 1891. Prior to its construction, a floating dry dock was used. A second dry dock was completed in 1910. After these two structures were completed, wooden wharves were replaced with concrete and steel quay walls supporting railroad track, effectively extending the shipyard boundary further into Mare Island Strait. Dry Docks 3 and 4 were constructed in the 1930s and 1940s, respectively.

Early in the development of the shipyard, the DON began testing experimental submarines at Mare Island. In 1904, a submarine wharf was constructed just south of Dry Dock 2. Because of its success with test craft, the DON established a base for submarine construction and maintenance in the early 1920s on reclaimed land north of the wooden causeway (today between A and G Streets). The first submarine built at Mare Island was launched in 1930. As the submarine repair base expanded, other related development took place in this area. Specifically, a petroleum storage and refueling area with aboveground and underground storage tanks was established alongside the quay wall at Berth 4, and maintenance and repair shops for the lead-acid submarine batteries were constructed east of the fuel storage area (Buildings 461, 463, and 463A).

In 1923, an airfield was constructed northwest of the submarine base immediately north of A Street on the west side of California Street, but it was no longer in use by 1924. The airfield was officially deactivated in 1937. After the concrete causeway was completed in 1935, additional shipbuilding ways were established just north of the causeway for small craft construction. Housing, warehouses, a paint manufacturing facility, and additional docks were also built in this area.

Near the end of the 1930s, the workers in the shipyard began using radium paints for manufacturing equipment with luminescent dials and displays. Low-level radioactive materials were generally confined to the buildings in which they were used, but handling procedures were

not regulated. In later years, storage and handling of low-level radioactive materials were strictly controlled.

During World War II, Mare Island reached peak capacity for shipbuilding, repair, overhaul, and maintenance. More than 40,000 workers were employed and 390 new ships (including landing craft, destroyers, and submarines) were built during this era. In addition, 1,207 ships of all types, including cruisers and submarines, were repaired and overhauled.

After World War II, Mare Island was considered one of the primary stations for construction and maintenance of the DON's submarines Pacific fleet. Decreasing needs in the postwar environment, however, resulted in decreased shipyard activity. In particular, activity north of G Street declined and, as a result, housing in the area was removed; shipbuilding ways were no longer used; and docks were built for storage of reserve (inactive) vessels. The paint manufacturing facility was closed in the mid-1950s and only the warehouses remained in use. The shipyard was then modified to allow construction of nuclear-powered submarines as well as storage and handling of nuclear materials. The first nuclear-powered submarine constructed at Mare Island (the *USS Sargo*) was launched in 1957. Seventeen nuclear-powered submarines were constructed over the course of operations at the shipyard.

2.1.3 Dredge and Fill Activities

Starting in the late 19th century, frequent dredging of the waterfront adjacent to Mare Island was required to maintain shipping lanes. At that time, the Sacramento River carried large quantities of silt that had been eroded by large-scale hydraulic mining activities in the Sierra Nevada. A portion of this material traveled downstream and was deposited in San Pablo Bay. In the absence of major streams or sloughs on the western side of Mare Island, sediment settled out of the water and tended to accumulate along the western shoreline.

In 1908, Dike 12 was constructed on the southern end of the island to reduce the amount of sediment in San Pablo Bay that could be flushed back into the Mare Island Strait with the tide. As a result, sediment accretion along the western shoreline of Mare Island increased and the island mudflat areas expanded. By the late 1930s, most of this area had become a mudflat as a

result of sedimentation caused by the presence of Dike 12. Beginning in the late 1930s, slurry from ongoing dredging operations in Mare Island Strait was intermittently pumped across Mare Island into two large impoundments (commonly referred to as dredge ponds) created by constructing levees within the mudflats on the western portion of the island. After allowing the solids to settle for a few days or weeks, the clarified water from the ponds was discharged to the western tidal marsh (currently IA J) and San Pablo Bay through a series of weirs and ditches. A large volume of dredge material accumulated as a result of this process. Large areas of land were reclaimed by filling ponds to the north, west, and south of the shipyard with material from frequent dredging in the shipping channel and pier areas of Mare Island Strait. Over time, a number of additional dredge ponds were formed by creating new berms within and outside the existing ponds as well as by extending the network of pipes and outfalls. As the ponds reached capacity, new berms were constructed further west to form new dredge ponds.

IA-H1 is composed of large areas of land that were reclaimed with spoils from frequent dredging in the ship channel and pier areas. Figure 2-3 shows how the historic dredge and fill disposal areas formed at Mare Island and gives a timeframe for when the dredge ponds were created.

The DON constructed levees in the mudflat areas along the western shoreline to hold dredge material pumped from Mare Island Strait. Currently, there are seven managed dredge ponds capable of receiving dredge material: six along the western shore (Ponds 4N, 4M, 4S, 2N, 2M, 2S) and one at the southern end of the island (Pond 7) as shown in Figure 2-2. Five filled, inactive dredge ponds (Ponds 1, 3N, 3E, 3W, and 5N) are also located northwest of IA-H1 as shown in Figure 2-2, and two ponds (Ponds 8 and 9) are located in the Western Magazine Area (WMA).

The region north of the original island (north of A Street), where the submarine repair base was built, was an area of tule marshes. Much of the land between A and G Streets was filled with materials excavated during early construction activities in the original shipyard. These activities included dry dock excavation and land grading in the area referred to as Dublin Hill, near the northern end of the original island. Filling with dredge material and other materials from shipyard activities primarily reclaimed the land further north of G Street.

2.1.4 Manufacture and Storage of Munitions

Since the beginning of naval operations at Mare Island, ordnance was stored at the southern end of the island, away from the shipyard and residential areas. By 1857, the DON had constructed the first ammunition magazine, and soon thereafter, a loading wharf was completed. Later development included additional magazines, ordnance-production facilities starting in 1936, and ordnance-handling piers.

The area was upgraded to a Naval Ammunition Depot (NAD) in 1936. In 1957, NAD operations merged with the Naval Magazine Port Chicago, located across the Carquinez Strait at Bay Point, near the City of Concord. The consolidated installation was named "Naval Weapons Station Concord." As a result, the area of munitions storage and maintenance operations at Mare Island was commonly referred to as the "Concord Annex."

A pond (Pond 7S) was constructed to hold materials dredged from around the ordnance-loading piers at the southern shoreline of the Concord Annex area near Dike 12. The dredge pond was eventually filled and a second dredge pond (Pond 7) was established. During the years of ordnance production, certain fill areas near Dike 12 and the historical dredge pond were used for burning and burying ordnance and ordnance production waste. This area was included in the Installation Restoration (IR) program as IR05.

In 1973, ordnance production activities in the Concord Annex ended. Many key production buildings, magazines, and warehouses were subsequently used to store inert materials and other supplies. Some were converted for use as office space, such as the United States Coast Guard station at the southeastern tip of the Concord Annex.

No records exist describing disposal of munitions or explosives of concern (MEC) within IA-H1. Several live 20 millimeter (mm) and 40 mm cannon projectiles were recovered in 1993 from a location between IR02 and the RCRA Landfill in and around Wetland X. Subsequent visual surface sweeps of the area revealed additional ordnance-related material including smokeless propellant containers and what appeared to be burned ordnance slag. In the IA-H1, all ordnance-related material was found inside the Containment Area. No such materials have been documented in the Upland or Non-Tidal Wetland Areas.

2.1.5 Waste Disposal Practices

The most significant land disposal activities took place at IA-H1 from the late 1930s to 1989. Table 2-3 lists the types of wastes generated by the MINS and disposed of within IA-H1. The following is an overview of these activities.

From 1910 to 1930, construction debris and solid waste were disposed outside IA-H1 north of A Street between Cedar and Walnut Avenues. From 1925 to 1942, construction debris and solid waste were disposed outside IA-H1 north of Dump Road and west of Cedar Avenue (now Azuar Drive). From 1942 to 1966, dumping occurred in the undeveloped areas of IA-H1, including portions of the Landfill Area, Northwest Dump Road Subarea, West Subarea, Solid Waste Disposal/Lead Oxide Storage Subarea, and Sludge Treatment/Surface Impoundment Subarea. These areas, referred to as "Historical Disposal Areas", are shown in Figure 2-4. Types and volumes of waste received at the Historical Disposal Areas were not documented, but the wastes are assumed to consist primarily of shipyard construction debris and municipal wastes. Spent sandblast abrasives, waste paints, solvents, acids, caustics, plating bath wastes, mercury wastes, forklift and submarine batteries, waste oil, sludge, grease, polychlorinated biphenyl (PCB)-contaminated fluids and clothing, pesticide containers, scrap metal and wood, infectious wastes from the dispensary, radium-containing equipment, and asbestos were suspected to be among the waste disposed of in the Historical Disposal Areas (Ecology and Environment, Inc. [E&E], 1983).

Waste oil was discharged to unlined oil sumps constructed within IA-H1 in the late 1930s and early 1940s; the sump area was later designated as IR02. The sumps reportedly received approximately 4.5 million gallons of waste oil and solvents before the site was backfilled in the late 1960s (E&E, 1983). An unknown but likely considerable volume of the waste oil discharged to the sumps was reclaimed. A former Mare Island Navy employee (Mr. Lemmon) was contacted by WESTON and confirmed that a Navy contractor recovered oil from the sumps. According to the employee, the contractor had separators and heaters that were used during the process of recovering the oil and he said the contractor was out there (IA-H1) for about 6 or 7 months after the Navy had stopped discharging into the sumps (Lemmon, 2006).

By the mid-1960s, levees were constructed within IA-H1 to define a waste disposal area west of the oil sumps along Dump Road. This 30-acre disposal area, referred to as the "Facility Landfill," was used to dispose of shipyard wastes. The Facility Landfill accepted the same type of wastes disposed of in the Historical Disposal Areas. When the Facility Landfill reached capacity in 1978, a new landfill was established on top of its western portion. This new landfill (referred to as the "RCRA Landfill" because it operated under RCRA interim status) was prohibited from accepting hazardous wastes with the exception of asbestos-containing materials, solvent-laden rags, paint sludge, and spent sandblast abrasives. Hazardous wastes prohibited from the RCRA Landfill were disposed of off site. The RCRA/Facility Landfill was closed in 1989; thereafter, all solid wastes were disposed of off site. The RCRA/Facility Landfill is estimated to contain 600,000 cubic yards of refuse, at a maximum thickness of 45 feet in certain places. Included in the Containment Area are the IA-H1 areas where most of disposal activities took place: the RCRA Landfill; the RCRA-regulated IWTP and surface impoundments; the Facility Landfill; the IR02 oil sumps; portions of IR16; and adjacent uplands and seasonal wetland areas. Figure 2-5 shows an aerial view of IA-H1 overlaid with the boundaries of the Containment Barrier, the RCRA-regulated units, and Facility Landfill. The IWTP pipeline shown on the figure was cleaned and inspected in November 2005 in accordance with the approved Installation and Restoration Site 14 Closure Plan (WESTON, 2005e). A closure report of the IWTP pipeline was submitted to DTSC in February 2006. Final closure of the IWTP will be requested as part of the RAP/ROD.

In 2004, a 7,300 linear foot vertical Containment Barrier (slurry wall) was constructed to depths of 25 feet and the associated groundwater extraction trench was constructed to depths of 15 feet. Debris encountered during installation of these facilities consisted predominately of demolition debris (concrete, metal and wood). Along the southern portion of the RCRA Landfill, plastic-bagged garbage was encountered during excavation of the groundwater extraction trench inside of the slurry wall alignment. Along the slurry wall alignment west of the landfill, a green color was noted in the groundwater. e trench. The green color was associated with a cache of discarded life jackets found at the same location, and is presumed to be a dye that would be released by someone in the water to assist rescuers in locating the victim. This dye should not be hazardous. The construction went through IR16, which was contaminated with lead oxide. Soil within the

planned alignment of the slurry wall and extraction trench was excavated and staged on a lined pad within the footprint of the Containment Area. Some oily soil and debris was encountered during the construction of the extraction trench within the interior of the slurry wall in the vicinity of the oil sumps at the southeastern corner of the Containment Area. This oil-stained soil was also staged inside the Containment Area. Several inert (dummy) munitions items were recovered from the slurry wall/groundwater extraction trench directly west of the RCRA Landfill boundary, and munitions-related debris was observed north of the RCRA Landfill boundary. No live munitions items were encountered during the slurry wall or groundwater extraction trench excavations. These observations are documented in the field log books and notes taken by the geologists and in the Construction Completion Report (WESTON, 2005c). Based on the historical review, the RCRA/Facility Landfill received hazardous waste type materials; the remaining portion of the Containment Area received waste oil, construction debris, and largely undocumented hazardous and non hazardous wastes.

2.2 SITE PROFILE

2.2.1 Summary of Remedial Investigation Activities

The MINS was closed on 1 April 1996 (after 142 years of operation) in accordance with the United States Department of Defense (DOD) Base Realignment and Closure Act of 1993. In accordance with the Federal Facilities Site Remediation Agreement, dated 29 September 1992 (California Department of Toxic Substances Control [DTSC], 1992), the Naval Facilities Engineering Command, Engineering Field Activity West (EFA WEST) was responsible for completing an RI at the MINS. Under Contract No. N62474-94-D-7609 and Contract Task Order No. 235, EFA WEST authorized Tetra Tech EM, Inc. (TtEMI), formerly PRC Environmental Management, Inc. (PRC), and the teaming firm LFR Levine-Fricke to prepare a Revised Preliminary Draft RI report for IA-H1 at Mare Island. The RI for sites within IA-H1 was previously reported in the draft RI reports for Operable Units 2 and 3 (PRC, 1997; PRC, 1996); however, the updated draft document included only the sites within IA-H1. The primary purpose of TtEMI's RI report, dated 12 May 2000, was to detail the nature and extent of any contamination and, as appropriate, to conduct a baseline risk assessment (consisting of a human

health risk assessment [HHRA] and an ecological risk assessment [ERA]), and to evaluate whether available data were adequate to perform site FSs.

The TtEMI RI for IA-H1 was part of the DON's Installation Restoration Program (IRP) for Mare Island. An Initial Assessment Study (E&E, 1983) and Phase I of the RI (International Technology Corporation [IT], 1992) were previously conducted under the IRP. Based on the results of the IT Phase I RI and several site-specific studies with similar objectives, 24 IR sites were eventually identified for inclusion in the Phase II RI.

The 24 IR sites were also referred to as the Group I sites. Sites that were identified through the preliminary assessment and site inspection screening process are considered Group II sites. Other sites of potential concern, identified through a fenceline-to-fenceline review of the MINS conducted by the DON, regulatory agencies, and the Restoration Advisory Board (RAB), are referred to as Group III sites.

The RI for Group I through III sites was conducted concurrently with base closure activities at Mare Island.

To ensure that reuse priorities were considered in determining the focus and schedule for environmental cleanup efforts, the DON, in consultation with regulatory agencies, divided the installation into IAs. These IAs were intended to generally coincide with the reuse zone boundaries identified in the City of Vallejo's reuse plan (City of Vallejo, California, 1994). The 2000 TtEMI RI focused on areas within IA-H1. These areas shown in Figure 2-4 included Group I IR sites IR01 (Undeveloped Area), IR02, IR06, IR14, IR16 B1/B2, IR16 B3/B5, IR24, and one Group II/III site, the SSTP overflow pond. IA-H1 also includes areas of former dredge ponds that are currently non-tidal seasonal wetlands.

WESTON revised the TtEMI Draft RI and submitted two separate Draft RIs for soil and groundwater at IA-H1. The Draft Soil RI, dated September 2002, included IA-H1, IR05, and the WMA (WESTON, 2002a). The Draft Final Groundwater RI, dated May 2002, included IA-H1 groundwater (WESTON, 2002b). Based on comments for these two RIs, WESTON developed a Data Gaps Sampling Plan (WESTON, 2003) to implement additional soil borings, groundwater sampling, and cone penetrometer testing (CPT) to complete contaminant nature and extent

determination and further soil and geologic/hydrogeologic characterization. The results of the data gaps sampling was then incorporated into a combined soil/groundwater Draft Final RI for IA-H1 (WESTON, 2004a) and Final RI for IA-H1 (WESTON, 2005a)

2.2.1.1 Interim Remedial Action

WESTON prepared a Final Action Memorandum/Interim Remedial Action Plan (AM/IRAP) to document the DON's decision to undertake a Time Critical Removal Action within IA-H1 (WESTON, 2004b). The IA-H1 AM/IRAP involved constructing a vertical groundwater Containment Barrier and a groundwater collection trench around a portion of the perimeter of the Mare Island historical landfill. The Final AM/IRAP was signed and approved by DTSC and DON in March 2004, and the work completed in September 2004. The area enclosed by the Containment Barrier and collection trench is located in the middle of the western portion of Mare Island and occupies approximately 70 acres. The vertical containment barrier was aligned to enclose the known and suspected primary sources of groundwater contamination including the Landfill Area, and portions of the Sludge Treatment/Surface Impoundment Area (IR02), the Waste Sump/Lead Oxide Storage and Disposal Area (IR02 and IR16 Subareas B1/B2), the Solid Waste Disposal/Lead Oxide Storage and Disposal Area (IR16 Subareas B3/B5), the Northwest Dump Road Subarea, the IWTP pipeline (IR14), and the West Subarea as shown in Figure 2-4,

The Containment Barrier surrounds at least three potential sources of groundwater contamination in IA-H1 and eliminates lateral migration of hazardous substances and contaminants of concern within the shallow groundwater, and reduces the potential for vertical migration of contaminants. As part of the IRAP preparation activities, lead-contaminated soil within IR16 Subareas B3/B5 was excavated and staged inside the Containment Area to allow construction of groundwater and compressed air conveyance piping and a groundwater treatment building within IR16 Subareas B3/B5. Also in 2005, a Time Critical Removal Action performed at the Mare Island Marine Corps Firing Range produced 37,270 cubic yards of material that was similarly or less contaminated than the materials already in the IA-H1 Containment Area. This material was stockpiled in the Containment Area pending a final decision on the remedy for IA-H1. This

stockpiled and/or similar material from Mare Island may be used to provide a base upon which to build a RCRA or non-RCRA hazardous waste cap.

2.2.2 Geology

The geology of the Mare Island peninsula described in the following text is based on published literature and site-specific lithologic data from current and previous Mare Island investigations. The geology of Mare Island is schematically illustrated in Figure 2-6, which is a block diagram that shows the stratigraphic relationships of the various units described in this section.

The geology of Mare Island can be characterized as an eroded bedrock surface exposed in the southern part of the peninsula. On the remaining portions of the island, the bedrock surface is overlain by unconsolidated Quaternary sediments and artificial fill material. The eroded bedrock forms a subsurface ridge that extends to the northwest along the axis of the Mare Island peninsula. The northern extent of the subsurface bedrock ridge is not known, but the ridge is present at least as far north as A Street. The bedrock surface is irregular and deeply incised in some areas. Based on recent CPT investigations, up to 186 feet of unconsolidated materials overlie bedrock in the area of the IA-H1 landfill (Figure 2-7).

Three principal geologic units have been identified at Mare Island. These include, from top to bottom stratigraphically, artificial fill material, unconsolidated natural deposits, and bedrock. The artificial fill material is a heterogeneous unit consisting of clay, silt, sand, gravel, and debris in varying proportions. The unconsolidated natural deposits consist primarily of a thick sequence of silty clays commonly referred to as “Young Bay Mud” as well as intermediate and lower sand units of the San Antonio Formation. The bedrock consists of sandstone, siltstone, and shale. The following sections describe each geologic unit in detail.

2.2.2.1 Artificial Fill

As a result of the extensive land reclamation activities at Mare Island, a highly heterogeneous, surficial layer of fill material is ubiquitous at locations outside the original outline of the island. Sand, gravel, organic debris, concrete, asphalt, brick, metal, timber, paint chips, fiberglass, and

other solid refuse are common in the artificial fill unit in the industrial areas of Mare Island and in IA-H1. The distribution of these materials is random, and significant variations in composition are observed over short lateral and vertical distances.

Early geological investigations inaccurately mapped surficial materials at Mare Island as Quaternary alluvium and Bay Mud (Simms *et. al.*, 1973; Dibblee, 1981), Quaternary artificial fill and marshland (Frizzell, *et. al*, 1974), and Quaternary alluvium and intertidal deposits (Wagner and Bortungo, 1982). In addition, Pleistocene nonmarine sediments, which are not artificial materials, have been mapped as surficial materials (Kahle and Goldman, 1966).

Silty clay sediment from the DON's land reclamation and channel-dredging activities is the predominant fill material at Mare Island. Slurry from dredging operations has been intermittently pumped into dredge ponds at various locations on Mare Island since 1914. Sediments from these ponds (also referred to as "dredge material") are composed mostly of dark gray, silty clay.

The thickness of the fill material is difficult to estimate because the dredge materials are not readily distinguishable from the natural deposits in many locations. At locations where the fill can be distinguished from naturally deposited materials on the basis of differing lithologic characteristics, fill thickness varies from a minimum of 1 to 2 feet to a maximum of approximately 43 feet within an elevated area of the southern portion of the RCRA/Facility Landfill. In most areas of Mare Island outside the outline of the original island, the fill has an estimated thickness of 4 to 8 feet.

2.2.2.2 Unconsolidated Natural Deposits

The second principal geologic unit at Mare Island is the unconsolidated natural deposits that unconformably overlie the eroded bedrock surface. The natural deposits consist of an upper silty clay, an intermediate sand, a lower silty clay, a thick, nearly continuous lower sand unit, and various sand lenses within a silty clay unit. The deepest silty clay unit and the sand lenses directly overlie the eroded bedrock surface, depending on the location. Each unit is discussed in detail in the following subsections.

2.2.2.2.1 Stratigraphic Nomenclature of Unconsolidated Natural Deposits

The depositional history of San Francisco Bay has been dominated by rising and falling sea levels in response to Pleistocene glacial events. Sediments were deposited in a thick sequence of alternating silty clay and sand units, and these units appear to be the transgressive and regressive deposits associated with the changes in sea level (Helley, *et. al.*, 1979). Treasher (1963) and Goldman (1969) report that up to 300 feet of unconsolidated sediments have accumulated in San Francisco Bay. Discontinuities in the silty clay and sand units and a general lack of distinguishing lithologic features have frustrated researchers in their attempts to define a uniform stratigraphic nomenclature to describe these sediments. Trask and Ralston (1951) identified an uppermost unit consisting of soft mud; medium-grained, silty sand; and silty clay as "Bay Mud" and an underlying windblown sand as "Merritt Sand." Treasher (1963) renamed the upper unit "Young Bay Mud" and divided it into an overlying soft member and a deeper, semiconsolidated member. Treasher (1963) in turn renamed the unit beneath the Merritt Sand the "Old Bay Mud" and noted that the Old Bay Mud is distinguished from the Young Bay Mud by degree of consolidation. Goldman (1969) reiterated this distinction and added that the degree of consolidation of the Old Bay Mud exceeds the expected consolidation from compression by overlying sediments and dewatering.

Based on the work of these researchers, the sedimentary assemblage present at Mare Island can be tentatively assigned to stratigraphic units. The upper silty clay, intermediate sand, and lower silty clay, as described below, on the western side of the bedrock ridge appear to correspond to Young Bay Mud, Merritt Sand, and Old Bay Mud, respectively. The thick, silty clay deposits east of the bedrock ridge are tentatively designated as Young Bay Mud, but these deposits may be levee deposits associated with the Napa River and may not be equivalent to Young Bay Mud in the Bay Area. In areas where bedrock is shallow, Old Bay Mud was not found to be present.

2.2.2.2.2 Young Bay Mud

Young Bay Mud is a marine/estuarine silty clay, deposited during the Holocene Epoch, within the last 10,000 years. Young Bay Mud consists of a soft, uniform, gray silty clay containing occasional thin, discontinuous sand lenses and shell fragments and is generally unconsolidated, soft, and highly compressible. The upper 4 to 6 feet of Young Bay Mud has been weathered and

desiccated and is often stained black. At greater depths below the desiccated crust, Young Bay Mud is gray to olive-gray in color, soft, highly plastic, and highly compressible. Silt content may vary with depth. Minor, widely spaced, discontinuous sand seams may also be present.

Young Bay Mud is relatively uniform across the western side of the Mare Island peninsula and is similar to the dredge materials that form the bulk of the artificial fill in the dredge ponds. In general, the Young Bay Mud increases in thickness to the west (toward San Pablo Bay) and to the northwest, reflecting a steep topographic drop in the bedrock surface. The unit varies from approximately 5 feet thick on top of the bedrock ridge up to approximately 40 feet thick near the western boundaries of Ponds 2N, 2M, and 2S, based on soil boring data (Subsurface Consultants, Inc., 2001a, 2001b).

The Young Bay Mud at Mare Island has a relatively low permeability. Aqua Terra Technologies (Aqua Terra) laboratory test reports (1986) indicate hydraulic conductivity values ranging from approximately 1.4×10^{-7} centimeters per second (cm/s) to 3.6×10^{-9} cm/s. Permeability testing performed in 2003 indicates hydraulic conductivity values ranged from 4×10^{-8} to 2×10^{-7} cm/s. Based on its thickness, extent, and permeability, the Young Bay Mud limits the amount of groundwater that can flow vertically through it and serves as an effective aquitard.

2.2.2.2.3 Late Pleistocene Alluvium

Late Pleistocene alluvium underlies the Young Bay Mud. It was deposited approximately 10,000 to 40,000 years ago in alluvial, estuarine, and marine environments when sea levels were lower than those at present.

The depth to the Late Pleistocene alluvium ranges from about 15 to 30 feet below ground surface (bgs), but is found at depths of up to approximately 50 feet bgs in some areas west and southwest of the RCRA/Facility Landfill. Where present, this unit occurs as a lenticular (lens-shaped) body of gray, predominantly fine-to medium-grained sand with localized areas that contain lesser amounts of silt and clay to localized areas that grade to predominantly silt. This unit is identified as the Intermediate Water-Bearing Zone (IWBZ). The intermediate sand is found at increasing depths beneath the IA-H1 and pinches out to the north, west, and south of the RCRA/Facility

Landfill Area. A geometric mean of 6.8×10^{-4} cm/s has been reported for *in-situ* hydraulic conductivity tests completed in this layer.

2.2.2.2.4 Old Bay Mud

Old Bay Mud is a late Pleistocene deposit of unoxidized, marine/estuarine, stiff to very stiff, silty clay. This lower silty clay unit is variable in color with irregular dimensions. It was deposited approximately 90,000 to 125,000 years ago during a time when sea level was at or near current levels. The Old Bay Mud forms a relatively continuous layer extending a considerable distance inland from the present shoreline, but may have been locally incised by erosion during the Wisconsin glacial period between 11,000 and 90,000 years ago when sea levels were considerably lower than those at present. This unit varies in thickness from approximately 3 to 18 feet (where the intermediate sand unit is present). The thinnest portion of Old Bay Mud deposits was encountered beneath the RCRA/Facility Landfill Area, approximately a few feet thick.

Old Bay Mud, while mineralogically similar to Young Bay Mud, has been preconsolidated to a considerable degree and forms a competent foundation material. Old Bay Mud is generally relatively dense and stiff, has a low permeability, and forms an aquitard locally between the IWBZ (where present) and Deep Water-Bearing Zones (DWBZs) at the site. Although no permeability testing has been completed on Old Bay Mud, hydraulic conductivity values are expected to be similar to Young Bay Mud ranging from 1×10^{-7} cm/s to 1×10^{-9} cm/s.

In areas where the intermediate sand unit pinches out, the upper contact of Old Bay Mud is in direct connection with the Young Bay Mud unit. Old Bay Mud typically contains an upper portion that is black or dark gray and a lower portion that is tan to olive gray. The upper surface of Old Bay Mud is irregular, reflecting a complex depositional history or differential consolidation following deposition.

2.2.2.2.5 Pleistocene Alluvium

Pleistocene alluvium was deposited beginning as early as 1,000,000 years ago. These sediments were deposited primarily in alluvial environments but may also include deposition in estuarine

environments. Sediments include both oxidized alluvial (brown/yellow) and unoxidized (blue/gray/green) marine layers as the depositional environment changed with the rise and fall of sea level and basin subsidence. Deposition and subsequent erosion of the Pleistocene alluvium ceased approximately 125,000 years ago when Old Bay Mud deposition began. A geometric mean hydraulic conductivity of 2.1×10^{-3} cm/s has been reported for *in-situ* tests completed in the uppermost sand deposit (WESTON, 2001).

Boring and CPT logs indicate that the uppermost portion of the Pleistocene Alluvium is a continuous sand to silty sand to sandy silt deposit, located at depths of about 30 feet bgs to greater than 65 feet bgs. The continuous sand deposit and the sand lenses comprise the deep water-bearing zone (DWBZ) at the site, and represent the bottom of the uppermost aquifer. This deposit is continuous throughout most of IA-H1, and is nearly connected to the intermediate sand beneath portions of the landfill where only a few feet of clay separate the sand units. Beneath the DWBZ sand unit is predominantly a clay unit interspersed with sand to silty sand lenses. Figure 2-7 shows a generalized geological cross section of the area. These clay deposits are over 100 feet thick beneath the RCRA/Facility Landfill and extend from the bottom of the DWBZ to bedrock. This deposit is continuous throughout most of IA-H1, and is nearly connected to the intermediate sand beneath portions of the landfill where only a few feet of Old Bay Mud separates the sand units. Beneath the sand unit is predominantly a clayey material, with interspersed sand to silty sand lenses. In some instances these sand lenses directly overlie the bedrock. The continuous sand deposit and the sand lenses comprise the DWBZ at the site.

2.2.2.3 Bedrock

The bedrock at Mare Island consists of steeply dipping brown, orange, and tan arkosic sandstone, siltstone, and micaceous shale. Based on recent CPT results, the depth to bedrock was found to be irregular and to vary from about 41 to 186 feet bgs. The shallowest depth to bedrock was encountered along the eastern side of IA-H1, with depth increasing toward the west.

Bedrock outcrops exist in the hilly area at the southern end of the peninsula that is now occupied by a golf course, ammunition bunkers, and a residential area along Mesa Avenue. The exposed bedrock at Mare Island is assigned to the undifferentiated Great Valley Sequence on Wagner and

Bortungo's regional geologic map (1982). A more detailed map prepared by Dibblee (1981) identifies the bedrock as arkosic sandstone and micaceous shale of the Cretaceous Panoche Formation. The Great Valley Sequence is a wedge of siliciclastic sediments that is up to 30,000 feet thick (Oakeshott, 1978) and encompasses several formations, including the Panoche Formation. The Great Valley Sequence has been thrust westward over the Jurassic Franciscan Complex; therefore, rocks of the Franciscan Complex are probably present at depth below Mare Island.

Dibblee differentiated the bedrock outcrop at Mare Island into two units. He tentatively identified the bedrock at the extreme southern end of Mare Island as an arkosic sandstone member of the Panoche Formation with steeply dipping beds overturned to the northeast. The remaining bedrock outcrop is mapped as Panoche Formation and consists of micaceous shale with minor thin sandstone beds dipping both gently and steeply to the southwest.

Kahle and Goldman (1966) have inferred that the northwest-trending Franklin Fault bifurcates and extends across the Carquinez Strait, intersecting the east and west flanks of the exposed bedrock outcrop. Subsequent maps (Dibblee, 1981; Wagner and Bortungo, 1982) do not indicate that the Franklin Fault extends across the Carquinez Strait. A report by TtEMI and Chow Engineering, Inc. (1998) also indicate that no known faults exist beneath the RCRA/Facility Landfill.

2.2.3 Hydrogeology

The hydrogeologic regime at Mare Island is composed of three principal water-bearing zones, including the shallow water bearing zone (SWBZ), IWBZ, and DWBZ. The SWBZ refers to both artificial fill and naturally deposited materials intersected by the water table. The IWBZ corresponds to the intermediate (Late Pleistocene Alluvium) sand. The DWBZ corresponds to the extensive lower (Pleistocene Alluvium) sand layer and deeper sand lenses that are separated from the sand layer by silty clay. Characteristics of the three water-bearing zones are presented in the following subsections.

2.2.3.1 Shallow Water-Bearing Zone

The SWBZ is the most shallow unit in which groundwater is encountered at Mare Island. The upper boundary of the SWBZ is the water table, indicating that this zone is unconfined. This zone is a heterogeneous unit consisting of saturated artificial fill material and the upper portion of the Young Bay Mud. The lower portion of the Young Bay Mud is apparently a zone of lower hydraulic conductivity separating the SWBZ from the IWBZ. The transition between the bottom of the SWBZ and the top of the zone of lower hydraulic conductivity within the Young Bay Mud is undefined but likely gradational and variable throughout Mare Island. Most shallow monitoring wells at Mare Island are screened in the SWBZ at depths of less than 20 feet bgs, and the screened intervals of these wells generally intersect the water table.

In general, groundwater in the SWBZ is encountered at depths ranging from the ground surface to approximately 9 feet bgs within IA-H1, with the exception that water levels in some wells located within the RCRA/Facility Landfill are slightly deeper due to the higher topography of the landfill surface. A comparison of water-level data collected during the various phases of the RI indicates that most SWBZ wells within IA-H1 exhibit moderate to strong seasonal variations in groundwater elevations: they are high during and immediately after the wet season (November through April) and are lower during and immediately after the dry season (May through October).

The groundwater extraction trench and the pump system currently control the groundwater levels and flow directions inside the Containment Barrier. Groundwater elevations as measured in the SWBZ during March 2005 (Q1) and August/September 2005 (Q3) are illustrated on the potentiometric surface maps included as Figures 2-8 and 2-9, respectively. Groundwater within the Containment Area flows radially outward from an area of mounded groundwater located in the vicinity of wells 01W18A and 01W19A toward the groundwater extraction trench sumps located around the inside perimeter of the Containment Area. The groundwater mound within the Containment Area is the result of infiltration of rainwater through the more permeable landfill material, resulting in recharge of the SWBZ groundwater.

Groundwater levels in the groundwater extraction trench sumps are lower than the levels measured in the monitoring wells outside the containment barrier. Continued operation of the groundwater extraction trench will reduce the groundwater mound and will maintain the head differential from outside the wall to inside. In the future, the impermeable cap over the Containment Area will further assist in maintaining lower water levels within the Containment Area. Continued operation of the extraction trench will also prevent migration of contaminants beyond the containment barrier. In addition, the head differential will preclude the outward flow of groundwater from the Containment Area.

Outside of the Containment Area, on the eastern, western, and northwest sides, groundwater flows to the west-northwest. Outside of the southern wall of the Containment Barrier, a groundwater mound is centered at well 01W35A with flow to the west and east.

2.2.3.2 Intermediate Water-Bearing Zone

The Pleistocene alluvium described in Section 2.2.2.2 comprises the IWBZ, which is present beneath the Young Bay Mud throughout most of IA-H1. The intermediate sand unit is a lenticular body of gray, fine to medium-grained sand and has localized areas containing lesser amounts of silt and clay. This unit was encountered at depths ranging from approximately 18 feet bgs (Wetland A area) to 50 feet bgs (IWTP Surface Impoundment Area) and was encountered at depths of 30 feet bgs or greater immediately around the RCRA/Facility Landfill. The intermediate sand attains a maximum thickness of approximately 13 feet in some areas and at well 01W48 and pinches out beneath the western side of the RCRA/Facility Landfill.

Groundwater elevations as measured in the IWBZ in March 2005 (Q1) and August/September 2005 (Q3) are illustrated on the potentiometric surface maps included as Figures 2-10 and 2-11, respectively. Review of these maps shows a similar groundwater flow pattern from each data set with flow generally to the west to northwest with an area of higher groundwater elevations located beneath the RCRA/Facility Landfill and SSTP area. The higher groundwater elevations beneath the RCRA/Facility Landfill and SSTP area appear to generally coincide with the mounded groundwater identified in the SWBZ. These elevations may be a reflection of pressure head buildup within the unit since the unit pinches out beneath the western side of the landfill

and/or the result of excess pore water pressure from the weight of the landfill mass and dredge pond berms. In addition, it does not appear that significant seasonal variations in the pattern of groundwater flow are occurring within the IWBZ. A direct connection between the SWBZ and IWBZ based on lithologic interpretation and pumping test results is not apparent. Groundwater elevations measured in wells screened in the IWBZ (as compared to water level elevations in the SWBZ wells) indicate that the two units are hydraulically separate, and the upper silty clay unit effectively confines groundwater in the IWBZ.

2.2.3.3 Deep Water-Bearing Zone

The DWBZ consists of the sandy Pleistocene alluvium deposits described in Section 2.2.2.2. The uppermost portion of this lower sand is a tan, fine to medium-grained silty sand unit encountered at depths of approximately 40 to 65 feet bgs in the vicinity of the RCRA/Facility Landfill. The depositional center of the uppermost portion of this sand unit appears to be oriented along a northeast-southwest axis and reaches its greatest thickness (25 feet) directly beneath the RCRA/Facility Landfill. The unit thins to the west and gradually dips toward the west. This uppermost portion of the DWBZ is nearly continuous throughout IA-H1. The deeper portions of the DWBZ consist of sand lenses within a silty clay unit. The potential for interconnection of the various sand lenses or units is possible; however, it is unknown whether a direct hydraulic connection exists.

Static groundwater elevations of approximately 45 feet above the top of the lower sand unit are routinely measured during the quarterly sampling events and indicate that groundwater in this zone occurs under confined conditions. Additionally, the DWBZ dips away from the original island margin, which leads to increasing depth of burial by less permeable silty clays farther from the original island. The primary sources of recharge for this unit are leakage from the IWBZs and infiltration at the original island margin.

A comparison of water-level data collected during the Phase I RI, quarterly monitoring rounds, and the Phase II RI, indicates that the DWBZ wells within the study area exhibit low to moderate seasonal variations in groundwater elevations. In general, groundwater elevations were generally

high during and immediately after the wet season (November through April) and were lower during and immediately after the dry season (May through October).

Groundwater elevations as measured in the DWBZ in March 2005 (Q1) and August/September 2005 (Q3) are illustrated on the potentiometric surface maps included as Figures 2-12 and 2-13, respectively. Review of these maps indicates that the DWBZ groundwater generally flows west - northwesterly.

2.2.4 Nature and Extent of Contamination

2.2.4.1 Groundwater

Based on the heterogeneous nature of the material and the presence of free product, the extent of SWBZ contamination inside the Containment Area is defined to include all of the groundwater underneath the Containment Area. The contaminants include mostly metals and petroleum products; trace levels of explosives, organotins, PCBs, pesticides, semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs) have been sporadically detected. The extent of manganese and nickel contamination encompasses all of the SWBZ within IA-H1. Various other constituents are limited to smaller areas within the SWBZ, including arsenic, copper, lead, molybdenum, nickel, bis(2-ethylhexyl)phthalate, total petroleum hydrocarbons (TPH) as diesel (TPH-d), and as motor oil (TPH-m). Alpha radium, gross alpha, gross beta, radium, radium 226, and radium 228 were detected in a majority of samples from the SWBZ inside and outside of the Containment Barrier. The detected concentrations thus far are considered to be consistent with naturally occurring radioactivity and radionuclides for this area.

The extent of lead and zinc contamination includes all of the IWBZ within IA-H1. Various other constituents are limited to smaller areas within the IWBZ, including antimony, copper, lead, manganese, mercury, molybdenum, nickel, tributyltin, and TPH-d. The extent of contamination in the IWBZ is assumed to be associated with natural processes. The tributyltin exceedances that occurred near two abandoned wells were most likely due to improper construction. TPH detections are also associated with the abandoned wells and are not considered representative of the IWBZ; in addition, the storage tank(s), which were the source of TPH contamination, have

been removed. Alpha radium, gross alpha, gross beta, radium, radium 226, and radium 228 were detected in all samples from the IWBZ. The detected concentrations thus far are considered to be consistent with naturally occurring radioactivity and radionuclides for this area.

The extent of aluminum, cadmium, lead, and zinc contamination includes all of the DWBZ within IA-H1. Various other constituents are limited to smaller areas within the DWBZ, including copper, manganese, mercury, and molybdenum. The extent of contamination in the DWBZ is assumed to be associated with natural processes. Alpha radium, gross alpha, gross beta, radium, radium 226, and radium 228 were detected in all samples from the DWBZ. The detected concentrations thus far are considered to be consistent with naturally occurring radioactivity and radionuclides for this area.

2.2.4.2 Soil

2.2.4.2.1 Containment Area

Wastes disposed of in the RCRA Landfill were segregated into three cells (construction debris, solvent-contaminated materials, and asbestos); the remaining portions of the Containment Area (non-RCRA areas) received waste oil in several oil sumps and construction debris, discarded equipment, and miscellaneous waste in a random manner. Propellant shipping containers were encountered in the Wetland X area. There is a possibility that MEC and radiological (RAD) items could be present within IA-H1; however, nearly all MEC and RAD items found at Mare Island in the vicinity of IA-H1 are associated with dredge pond outfalls, which are not located within IA-H1. Several classes of compounds, such as metals, pesticides, PCBs, polynuclear aromatic hydrocarbons (PAHs), VOCs, organochlorine pesticides, total petroleum hydrocarbons as gasoline (TPH-g), TPH-d, and TPH-m, have been identified in the surface and subsurface soil within the Containment Area. The two classes of contaminants that are clearly predominant in the non-RCRA area are metals and TPH. Metals and TPH contamination of surface and subsurface soil outside the RCRA/Facility Landfill is also widespread and is consistent with the history of disposal at the site. Although numerous sample analyses have been performed in the Containment Area, a full characterization was not performed because it is not required with the application of the presumptive remedy.

2.2.4.2.2 Upland Areas outside the Containment Barrier

The Upland Areas consist of many subareas with a layer of fill material under the surface soil. The fill often includes concrete, wood, asphalt, paper, rubber, rebar, pipes, and glass, and is often highly heterogeneous with no identifying point sources. The fill is likely the source of much of the Upland Areas contamination. Metals were identified above screening criteria in all of the subareas, but the metals concentrations generally decrease with depth, except chromium, which was found throughout all of the subsurface units. PCBs, pesticides, SVOCs, and TPH were frequently identified above screening criteria in each subarea, but were limited to a few sampling locations.

2.2.4.2.3 Non-Tidal Wetland Areas outside the Containment Barrier

Most of the areas within the Non-Tidal Wetland Areas are former dredge ponds, containing mostly dredge material overlying Young Bay Mud. The sources of contamination in these areas are likely the dredge material and stormwater runoff from adjacent contaminated areas, such as the Demolition Debris Subarea, Fire-Fighting Training Subarea, Defense Reutilization and Marketing Office, and Waste Sump Areas. Metals detected above screening criteria in the Non-Tidal Wetland Areas were often confined to the sediment, with the exception of chromium, which was found above screening criteria in underlying soils. Pesticide, PCB, SVOC, and TPH contamination were often limited to a few points in each of the subareas within or directly adjacent to the fill areas within the Upland Areas.

2.2.4.3 Landfill/Soil Gas

Based on limited sampling data (10 soil gas borings), it has been observed that landfill gas is being generated primarily within the RCRA Landfill portion of the Containment Area, and little is being generated within the remainder of the Containment Area (WESTON, 2005a). The non-methane organic compounds (NMOCs) identified during soil gas sampling and analysis at IA-H1 fall into three major groups: halogenated solvents, petroleum fuel constituents, and ketones (including alcohols and oxygen-containing compounds). The presence of these classes of chemicals is consistent with the subsurface materials at IA-H1, such as solvent-laden rags and waste petroleum products. Levels of NMOCs typically produced at a municipal landfill are 0.01

to 0.6 percent, according to the Agency for Toxic Substances and Disease Registry, *Landfill Gas Primer, An Overview for Environmental Health Professionals* (2001); in the RCRA-regulated units, the NMOC levels were 0.0092 percent, and outside the RCRA-regulated units, the NMOC levels were 0.000025 percent. Methane gas production within the RCRA Landfill is consistent with methane production at a typical municipal landfill. Methane production in a typical municipal landfill ranges from 45 to 60 percent. Methane in the RCRA-regulated units ranged from 25 to 38 percent, and levels outside the RCRA-regulated units ranged from 0.0064 to 2.9 percent. The results and differences in soil gas generation from the RCRA-regulated units to the remainder of the Containment Area will be considered in the design document to appropriately design gas collection, venting, and monitoring. Gas generation will be included in the monitoring program once the remedy is applied. These results will be verified after implementation of the remedy.

2.2.5 Contaminant Fate and Transport

2.2.5.1 Containment Area

Surface erosion by wind or water, volatilization from the subsurface materials to air, and the downward migration of contaminants with infiltration of rainwater are all considered potential migration pathways for soil contaminant migration within the Containment Area. Shallow soil particles with adsorbed contaminants may be eroded by wind or rainfall, suspended and transported in air or surface water runoff, and redeposited either on or off site. Infiltrating precipitation may serve as a pathway for soluble soil contaminants to migrate to the groundwater. The VOCs detected in soil may volatilize, migrate through the vadose zone, and in the absence of surface cover, vent to the atmosphere.

In the portions of the Containment Area where more permeable materials (refuse, sand, and gravel) are present in the shallow subsurface, contaminants are expected to migrate more rapidly than in other areas of the site where soil consists predominantly of silt and clay. Soluble contaminants in soil and refuse close to or within the zone of groundwater fluctuation may become mobilized and migrate as solutes in groundwater. Infiltrating precipitation may also serve as a pathway for soluble soil contaminants to migrate to the groundwater in areas with no

landfill cover. These contaminants may migrate to the groundwater, and contaminants in soil may solubilize and leach into groundwater. The mobility of organic compounds is expected to be limited by sorption onto fine-grained soil particles and organic material. The mobility of metals is expected to be limited by sorption to or formation of complexes with organic compounds in soils where soil pH is neutral to slightly basic (pH generally ranges between 6.8 and 8.7 in soils within the Containment Area).

At the boundary of the Containment Area, all debris and utility crossings have been removed and replaced with a three-foot thick soil-bentonite slurry wall keyed into the underlying clay a minimum of five feet, as part of the Interim Remedial Action discussed previously. This barrier effectively limits the horizontal migration of contaminants in the SWBZ within the Containment Area.

2.2.5.2 Upland Areas outside the Containment Barrier

The probable migration pathways for soil and groundwater contamination within the Upland Areas include surface erosion by wind or water, volatilization to air, the downward migration of contaminants with infiltration of rainwater, and transport by groundwater. Shallow soil particles with adsorbed contaminants may be eroded by wind or rainfall, suspended and transported in air or surface water runoff, and redeposited either on or off site. Volatile contaminants detected in groundwater may volatilize and diffuse into the vadose zone. Similarly, volatile contaminants in soil may volatilize. Once in the vadose zone, the contaminants can migrate through the vadose zone and vent to the atmosphere.

Infiltrating precipitation may serve as a pathway for soluble soil contaminants to migrate to the groundwater by leaching. The mobility of both organic and inorganic compounds is likely limited by sorption to fine-grained soil particles and organic material. Across much of the Upland Areas, migration of soluble contaminants in groundwater is expected to be limited because of the low permeability and the adsorbing characteristics of the silty soils.

Soluble contaminants in soil and refuse close to or within the zone of groundwater fluctuation may also become mobilized and migrate as solutes in groundwater. However, the mobility of

organic compounds in groundwater is expected to be limited by sorption onto fine-grained soil particles and organic material. The mobility of metals is expected to be limited by sorption to organic compounds or formation of complexes with organic compounds in areas where the groundwater pH is neutral to slightly basic. In areas where soil is slightly acidic, metals may have a greater tendency to migrate. However, lateral migration of contaminants in shallow groundwater within the Containment Area is controlled by the Containment Barrier (slurry wall and extraction system) installed in 2004.

Vertical migration of contaminants in groundwater from the SWBZ to the IWBZ and DWBZ may occur because of a downward hydraulic gradient between these zones. This migration is expected to be limited because of the low permeability (10^{-7} cm/s) of the silty clay layers separating these zones. However, many of the initially installed monitoring wells were constructed with screens that intersected both the SWBZ and the IWBZ. This created potential conduits for the downward migration of groundwater. As many of these monitoring wells were located within or adjacent to waste disposal areas, contamination may have migrated into the IWBZ. These wells have been properly abandoned and are no longer potential conduits

Migration of groundwater and dissolved contaminants in the SWBZ could be expected to be relatively fast in areas dominated by debris material and sand and gravel, where the hydraulic conductivity has been found up to about $5x10^{-3}$ cm/s. This pertains predominantly to the area within the Containment Barrier. However, the SWBZ in most of IA-H1 consists of silty clay material with a relatively low hydraulic conductivity ($3x10^{-5}$ to $1x10^{-7}$ cm/s). Additionally, the areas surrounding the waste areas of IA-H1 consist of silty clay dredge material and natural deposits. The result is a higher permeability material, surrounded by low permeability material, with off-site migration of dissolved contaminants governed by the permeability of the outer, low permeability material. Therefore, groundwater transport of dissolved contaminants is not expected to be significant. Additionally, the Containment Barrier will prevent future migration of contaminants from the enclosed waste areas, and is likely to lower the groundwater table just outside of it. This will result in a smaller hydraulic gradient, which will in turn result in lower rates of contaminant transport outside the Containment Barrier.

Where underground utilities have been buried in a permeable backfill, significant groundwater migration may occur in relatively permeable materials within the Upland Areas. For example, the permeable backfill surrounding the underground saltwater pipeline that passes along the northwestern boundary of the landfill, or the IWTP (IR14) pipeline that runs parallel to Dump Road, is considered a preferential pathway for groundwater transport or infiltrating precipitation.

2.2.5.3 Non-Tidal Wetland Areas outside the Containment Barrier

The probable migration pathways for soil contamination within the Non-Tidal Wetland Areas include surface erosion by wind or water, the downward migration of contaminants with infiltration of surface water or rainwater, and transport by groundwater. Shallow soil particles with adsorbed contaminants may be eroded by wind or rainfall, suspended and transported in air or surface water runoff, and redeposited either on or offsite. Volatile contaminants detected in groundwater may volatilize and diffuse into the vadose zone. Similarly, volatile contaminants in soil may volatilize. Once in the vadose zone, the contaminants can migrate through the vadose zone and vent to the atmosphere.

The fate of the metals found in the Non-Tidal Wetland Areas is controlled by reactions such as cation exchange, which would result in adsorption of contaminants to soil mineral surfaces or soil organic matter. Their fate will also likely be controlled by precipitation reactions leading to the formation of secondary mineral phases. The retention of metals by soil will depend on soil pH, mineralogical composition, oxidation-reduction conditions, and soil organic-matter content. The mobility of metals is likely limited by sorption to organic compounds in soils where soil pH is neutral to slightly basic. In the neutral to slightly basic and organic-rich conditions, the metals in the vadose zone will tend to remain adsorbed to soil; however, metals detected in soil below the fluctuating water table surface may dissolve.

Surface soil particles containing elevated metal concentrations are subject to wind and water erosion and may migrate as dispersed particulate dust in the atmosphere by wind action and/or as overland sediment load with surface runoff. The major transport pathways for the metals in the wetland areas will be particulate migration as fugitive dust, and dissolution into the surface water, followed by transport to the SWBZ groundwater. Once in the SWBZ, the metals could be

transported through advection, diffusion, and dispersion. However, the hydraulic conductivity of the SWBZ in the vicinity of the wetlands is expected to be low, due to the silty clay nature of the underlying soils, indicating that transport of metals in groundwater is not expected to be very effective. Additionally, metals in groundwater will be susceptible to adsorption to the silty clay and are likely to be further retarded against migration.

Surface soil particles containing PCBs are subject to wind and water erosion and may migrate either as fugitive dust in air or in surface water runoff. Natural attenuation processes are expected to be very slow for PCBs.

PAHs detected at various locations throughout the Non-Tidal Wetland Areas have a very low solubility in water, very low vapor pressure, and very high soil-water partitioning coefficient. Because PAHs do not readily volatilize and typically adsorb strongly to soil and organic matter, it is expected that they will remain adsorbed to soil with negligible transport to the SWBZ. Therefore, the fate of PAHs is likely to be dependent upon biodegradation processes and concentrations in soil will likely diminish over time as a result of natural attenuation processes such as degradation and dispersion.

2.2.6 Risk Assessment Summary

As stated in the Final RI for IA-H1 (WESTON, 2005a), an evaluation of the FS remedial alternatives is warranted if the human health and/or ecological risk estimates exceed the risk estimate criteria. If the human health and ecological risk estimates are less than the criteria, no further remedial action will be recommended, and only a limited streamlined FS is required. For human health, if potential cancer risk is within the target risk range (10^{-4} to 10^{-6}) and the Hazard Index (HI) for noncancer adverse health effects is greater than 1 for each target organ exposure, then risk management decisions will be required to determine remedial action recommendations and the scope of the FS. For ecological effects, if the Hazard Quotient (HQ) for an individual chemical is greater than 1 based on the high Toxicity Reference Value (TRV), then risk management decisions will be required to determine remedial action recommendations and the scope of the FS.

2.2.6.1 Human Health Risk Assessment

Three separate risk assessments were prepared for IA-H1 (WESTON, 2006). A Screening Level Risk Evaluation was conducted for soil, sediment, and groundwater within the proposed Containment Area; a baseline HHRA was conducted for soil, sediment, and groundwater in the Upland Areas; and a baseline HHRA was conducted for soil, sediment, groundwater, and surface water in the Non-Tidal Wetland Areas. The shallow groundwater was evaluated in two separate areas as divided by the Containment Barrier. The intermediate and deep groundwater were evaluated on a site-wide basis. Based on an evaluation of current and expected future uses of the site, the following human receptors were evaluated at the three exposure areas (i.e., Containment Area, Upland Areas, and Non-Tidal Wetland Areas) within IA-H1:

- Current/future commercial/industrial worker at the Containment Area (adult)
- Current/future recreational users at Upland Areas and Non-Tidal Wetland Areas (1- to 17-year-old children)
- Hypothetical current and future residents at Containment Area and Upland and Non-Tidal Wetland Areas (adults and 0- to 6-year-old children)
- Current/future construction workers at Upland and Non-Tidal Wetland Areas (adult)

The 0 to 2 feet bgs soil zone was used to represent current soil conditions. The 0 to 10 feet bgs mixed soil zone was used to represent future soil conditions. The mixed soil zone was evaluated to represent conditions in the event of any construction or digging that may occur at the site. Results from notable exposure scenarios are described in the following sections.

2.2.6.1.1 Current Exposure Scenario

Containment Area Commercial/Industrial Worker

The total lifetime excess cancer risk estimate for the current exposure scenario to a commercial/industrial worker for all exposure media within the Containment Area (i.e., soil and groundwater) is 1.9×10^{-3}. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 2 feet bgs zone is 2.9×10^{-4}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Containment Area is 1.6×10^{-3}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 3.8×10^{-6}. The

estimated HI is equal to 28 for combined soil and groundwater exposure. The estimated HI for soil exposure is equal to 6.0. The estimated HI for shallow groundwater exposure is equal to 22, and the estimated HI for combined intermediate and deep groundwater is equal to 0.05.

The chemicals of concern (COCs) for the current exposure scenario include arsenic, Aroclor-1248, Aroclor-1254, Aroclor-1260, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, 2-methynaphthalene, naphthalene, 1,4-dichlorobenzene, and 1,2,3-trichloropropane for soil and bis(2-chloroethyl)ether, benzene, chloroethane, 1,4-dichlorobenzene, 1,2-dichloroethane, 1,2-dichloroethene, tetrachloroethene, vinyl chloride, 2-methylnaphthalene, naphthalene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,1,2-trichloroethane, and xylene in shallow groundwater.

Upland Areas Recreational User

For the Upland Areas, the total reasonable maximum exposure (RME) lifetime excess cancer risk estimate for the current exposure scenario to a recreational user for all exposure media (i.e., soil and groundwater) is 5.2×10^{-5}. Arsenic, at or below ambient/background levels for this area, accounts for most of the carcinogenic risk. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 2 feet bgs zone is 5.0×10^{-5}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Uplands Area is 1.1×10^{-6}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater underlying the Upland Areas is 1.4×10^{-6}. The estimated HI is equal to 0.30 for combined soil and groundwater exposure. The estimated HI for soil exposure is equal to 0.21, the estimated HI for shallow groundwater exposure is equal to 0.068, and the estimated HI for intermediate and deep groundwater exposure is equal to 0.018.

The COCs for the current exposure scenario for the Upland Areas based on cancer risk estimates include arsenic and benzo(a)pyrene for soil. The total noncancer HI for combined exposure media did not exceed 1. No individual chemical had an individual HI greater than 1, and no individual target organ noncancer HI exceeded 1. No COCs were identified based on adverse noncancer health effects to humans.

Non-Tidal Wetland Areas Recreational User

For the Non-Tidal Wetland Areas, the total RME lifetime excess cancer risk estimate for the current exposure scenario to a recreational user for all exposure media (i.e., sediment, groundwater, and surface water) is 8.4×10^{-5}. Arsenic, at or below ambient/background soil levels for this area, accounts for most of the carcinogenic risk. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 2 feet bgs zone is 6.5×10^{-5}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Non-Tidal Wetland Areas is 1.1×10^{-6}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 1.4×10^{-6}. The total lifetime excess cancer risk estimate for exposure to surface water within the Non-Tidal Wetland Areas is 1.7×10^{-5}. The estimated HI is equal to 0.31 for combined sediment, groundwater, and surface water exposure. The estimated HI for soil exposure is equal to 0.20, the estimated HI for shallow groundwater exposure is equal to 0.068, the estimated HI for intermediate and deep groundwater exposure is equal to 0.018, and the estimated HI for surface water exposure is equal to 0.02.

The COCs for the current exposure scenario at the Non-Tidal Wetland Areas based on cancer risk estimates include arsenic for soil and surface water. The total noncancer HI for the current exposure scenario did not exceed 1. No individual chemical had an individual HI greater than 1 and no individual target organ noncancer HI exceeded 1. No risk drivers were identified based on adverse noncancer health effects to humans

2.2.6.1.2 Future Exposure Scenario

Containment Area Commercial/Industrial Worker

The total lifetime excess cancer risk estimate for the future exposure scenario to a commercial/industrial worker for all exposure media within the Containment Area (i.e., soil and groundwater) is 1.9×10^{-3}. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is 2.9×10^{-4}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Containment Area is 1.6×10^{-3}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 3.8×10^{-6}. The estimated HI is equal to 28 for combined soil and groundwater exposure. The estimated HI for

soil exposure is equal to 5.9, the estimated HI for shallow groundwater exposure is equal to 22, and the estimated HI for intermediate and deep groundwater exposure is equal to 0.05.

The COCs for the future exposure scenario at the Containment Area include arsenic, Aroclor-1248, Aroclor-1260, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, 2-methynaphthalene, naphthalene, 1,4-dichlorobenzene, and 1,2,3-trichloropropane in soil and bis(2-chloroethyl)ether, benzene, chloroethane, 1,4-dichlorobenzene, 1,2-dichloroethane, 1,2-dichloroethene, tetrachloroethene, 1,1,2-trichloroethane, vinyl chloride, 2-methylnaphthalene, naphthalene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and xylene in groundwater.

Upland Areas Recreational User

For the Upland Areas, the total RME lifetime excess cancer risk estimate for the future exposure scenario to a recreational user for all exposure media (i.e., soil and groundwater) is 5.5×10^{-5}. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is 5.3×10^{-5}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Upland Area is 1.1×10^{-6}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 1.4×10^{-6}. The estimated HI is equal to 0.36 for combined soil and groundwater exposure. The estimated HI for soil exposure is equal to 0.27, the estimated HI for shallow groundwater exposure is equal to 0.068, and the estimated HI for intermediate and deep groundwater exposure is equal to 0.018.

The COCs for the future exposure to a recreational user based on cancer risk include arsenic, total PCBs, and benzo(a)pyrene in soil. No chemical had an individual noncancer HI greater than 1 and no individual target organ noncancer HI exceeded 1. No COCs were identified based on adverse noncancer health effects to humans.

Upland Areas Construction Worker

For the Upland Areas, the total RME lifetime excess cancer risk estimate for the future exposure scenario to a construction worker for all exposure media (i.e., soil and groundwater) is 9.2×10^{-6}. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is 8.8×10^{-6}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater

underlying the Upland Areas is 2.1×10^{-7}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 2.7×10^{-7}. The estimated HI is equal to 1.5 for combined soil and groundwater exposure. The estimated HI for soil exposure is equal to 1.2, the estimated HI for shallow groundwater exposure is equal to 0.22, and the estimated HI for intermediate and deep groundwater is equal to 0.08.

The only COC for future exposure to a construction worker based on cancer risk is arsenic for soil. No chemical had an individual noncancer HI greater than 1 and no individual target organ noncancer HI exceeded 1. No COCs were identified based on adverse noncancer health effects to humans.

Non-Tidal Wetland Areas Recreational User

For the Non-Tidal Wetland Areas, the total RME lifetime excess cancer risk estimate for the future exposure scenario to a recreational user for all exposure media (i.e., sediment, groundwater, and surface water) is 8.3×10^{-5}. Arsenic, at or below ambient/background levels for this area, accounts for most of the carcinogenic risk (about 95 percent). The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is 6.4×10^{-5}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Non-Tidal Wetland Areas is 1.1×10^{-6}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 1.4×10^{-6}. The total lifetime excess cancer risk estimate for exposure to surface water within the Non-Tidal Wetland Areas is 1.7×10^{-5}. The estimated HI is equal to 0.36 for combined soil, groundwater, and surface water exposure. The estimated HI for soil exposure is equal to 0.25, the estimated HI for shallow groundwater exposure is equal to 0.068, the estimated HI for intermediate and deep groundwater exposure is equal to 0.018, and the estimated HI for surface water exposure is equal to 0.02.

The only COC for the future exposure to a recreational user based on cancer risk is arsenic in sediment and surface water. No chemical had an individual noncancer HI greater than 1 and no individual target organ noncancer HI exceeded 1. No COCs were identified based on adverse noncancer health effects to humans.

Non-Tidal Wetland Areas Construction Worker

For the Non-Tidal Wetland Areas, the total RME lifetime excess cancer risk estimate for the future exposure scenario to a construction worker for all exposure media (i.e., sediment and groundwater) is 1.1×10^{-5}. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is 1.1×10^{-5}. The total lifetime excess cancer risk estimate for exposure to shallow groundwater underlying the Non-Tidal Wetland Areas is 2.1×10^{-7}. The total lifetime excess cancer risk estimate for exposure to intermediate and deep groundwater is 2.7×10^{-7}. The estimated HI is equal to 1.6 for combined sediment and groundwater exposure. The estimated HI for sediment exposure is equal to 1.3, the estimated HI for shallow groundwater exposure is equal to 0.22, and the estimated HI for intermediate and deep groundwater exposure is equal to 0.059.

The only COC for future exposure to a construction worker based on cancer risk is arsenic in soil. Although the total noncancer HI for the future exposure for a construction worker exceeded 1, no individual chemical had an individual HI greater than 1, and no individual target organ noncancer HIs exceeded 1.

2.2.6.1.3 Exposure to Groundwater in a Shallow Trench

In addition to direct contact and inhalation of particulates and vapors exposure pathways, the inhalation of vapors from groundwater in a shallow trench exposure pathway was evaluated in the HHRA. The construction worker scenario assumes direct contact with contaminated groundwater and is presented separately from exposure to particulates and vapors.

Containment Area

The estimated cancer risk estimate for exposure to VOCs in shallow groundwater at the Containment Area during trenching activities is 5.5×10^{-7}. The estimated HI for exposure to VOCs in shallow groundwater in a trench is equal to 0.19. No risk drivers were identified for shallow groundwater exposure to a construction worker in a trench.

Upland Areas

The estimated cancer risk estimate for exposure to VOCs in shallow groundwater at the Upland Area during trenching activities is $3.7x10^{-9}$. The estimated HI for exposure to VOCs in shallow groundwater in a trench is equal to $2.9x10^{-3}$. No risk drivers were identified for shallow groundwater exposure to a construction worker in a trench.

Non-Tidal Wetland Areas

The estimated cancer risk estimate for exposure to VOCs in shallow groundwater at the Non-Tidal Wetland Areas during trenching activities is $3.7x10^{-9}$. The estimated HI for exposure to VOCs in shallow groundwater in a trench is equal to $2.9x10^{-3}$. No risk drivers were identified for shallow groundwater exposure to a construction worker in a trench.

2.2.6.1.4 Indoor Air Exposure

The current land use at IA-H1 is open space and the Final Mare Island Reuse Plan (City of Vallejo, California, 1994) established the anticipated future land use at IA-H1 as open space/recreational. Indoor air exposure at IA-H1 is hypothetical and is presented separately from direct contact and outdoor air exposure.

Containment Area

The total cancer risk estimate for indoor air exposure to soil and groundwater combined is $4x10^{-3}$. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is $4x10^{-3}$. The total lifetime excess cancer risk estimate for indoor air exposure to groundwater underlying the Containment Area is $1.9x10^{-5}$. The estimated HI for indoor air exposure is equal to 30 for combined soil and groundwater exposure. The estimated HI for indoor air exposure from soil at the Containment Area is 29. The estimated HI for indoor air exposure from groundwater at the Containment Area is 0.36.

Upland Area

The total cancer risk estimate for indoor air exposure to combined soil and groundwater for a recreational user at the Upland Areas is $1.3x10^{-5}$. The total lifetime excess cancer risk estimate

for exposure to soil within the 0 to 10 feet bgs zone is $1.3x10^{-5}$. Heptachlor ($3.4x10^{-6}$), benzene ($1.7x10^{-6}$), chloroform ($1.3x10^{-6}$), tetrachloroethene ($1.0x10^{-6}$), and trichloroethene ($5.4x10^{-6}$) had cancer risk estimates exceeding one-in-one million in soil. The total lifetime excess cancer risk estimate for indoor air exposure to groundwater underlying the Upland Areas is $1.8x10^{-7}$. The estimated HI for indoor air exposure is equal to 0.1 for combined soil and groundwater exposure.

Non-Tidal Wetland Areas

The total cancer risk estimate for indoor air exposure to combined soil and groundwater for a recreational user at the Non-Tidal Wetland Areas is $3.0x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to soil within the 0 to 10 feet bgs zone is $2.9x10^{-5}$. Methylene chloride ($1.7x10^{-6}$), trichloroethene ($3.7x10^{-6}$), and vinyl chloride ($2.4x10^{-5}$) had cancer risk estimates exceeding one-in-one million in soil. The total lifetime excess cancer risk estimate for indoor air exposure to groundwater underlying the Non-Tidal Wetland Area is $1.8x10^{-7}$. The estimated HI for indoor air exposure is equal to 0.19 for combined soil and groundwater exposure.

2.2.6.1.5 Human Health Risk from Munitions of Explosives of Concern Items

The risk of injury was assessed by evaluating the type and condition of MEC previously found in the Upland and Non-Tidal Wetland Areas of IA-H1 as well as the probability of coming into contact with MEC items.

Previous investigations have found limited MEC within the Upland and Non-Tidal Wetland Areas of IA-H1. The single instance where an MEC item was discovered in IA-H1 was a single fired 5-inch projectile. When detonated under controlled conditions this projectile showed that it was not filled with explosives and therefore was not energetic. This was discovered during excavation activities at IR16 in 2004. All other recovered MEC items in IA-H1 and from nearby Dredge Ponds within IA HI have been unfired with their associated fuse components deteriorated or inoperable due to corrosion. The condition of these MEC items is important because much of the MEC recovered had been degraded by the moisture rich environment where it was deposited, thereby decreasing the risk of detonation.

The majority (99.9 percent) of MEC items discovered and removed during the Survey and Removal Actions at the adjacent Dredge Ponds were recovered near the outfalls of the ponds. These outfall areas were completely excavated; all soil and debris were searched using handheld geophysical instruments and hand sorted by qualified personnel to remove all MEC items. A majority of the recovered items originated from the former outfall associated with Dredge Pond 4S. No outfalls are present within the boundaries of IA-H1. Based on the type, condition, and location of MEC items previously recovered throughout Mare Island, the probability of coming into contact with MEC/MC items at IA-H1 is low, but the possibility exists for encountering MEC or RAD in fill or disposal areas on Mare Island, such as IA-H1. In addition, the intrusive investigation/removal action likely removed a vast majority of MEC items from the surrounding dredge pond areas.

2.2.6.1.6 Human Health Risk from Radiological Items

The surface of the landfill, the IWTP Subarea, and the shallow groundwater in IA-H1 have been sampled or surveyed for radiological contamination. These surveys do not encompass the entire extent of IA HI and the potential that radiological items are present in the subsurface still exists. The base-wide survey included a survey of the surface of the landfill, a survey of the IWTS throughout the base, and sampling of 67 wells in IA-H1. Alpha radium, gross alpha, gross beta, radium, radium 226, and radium 228 were detected in all samples from the DWBZ. The detected concentrations thus far are considered to be consistent with naturally occurring radioactivity and radionuclides for this area. However, a search for radiological material in dredge outfall areas was performed and radiological items recovered typically consisted of a radioluminescent disk that provided a low level of light source on ships. It was concluded that IAs I and J still have a small risk for exposure to radiological items. Because IA-H1 also contains some former dredged materials as well as landfilled materials that may include discarded disks, there is also a small chance that some radiological items remain buried in the soil at this site as well.

2.2.6.1.7 Ambient/Background Risk

Ambient/background levels of materials may contribute significantly to the overall risk levels at a hazardous waste site. Ambient/background concentrations in soil vary as a result of both natural and anthropogenic soil-forming processes. Thus, the contribution of ambient/background

levels to the total risk needs to be considered when evaluating the risk posed by IA-H1. Within IA-H1, arsenic is a main contributor to the overall cancer risk. The 95 percent upper confidence limit (95UCL) arsenic level for Mare Island artificial fill is 14 milligram per kilogram (mg/Kg) based on a statistical calculation using an existing data set from the *Final Compilation of the Technical Memoranda on Ambient Analysis of Metals in Soil and Groundwater, Mare Island, Californi*a, prepared by TtEMI in 2002. The 95th percentile ambient/background concentration is 36 mg/kg. As shown in the Final RI (WESTON, 2006), the contribution of the ambient/background level of arsenic to the total risk is at least 90 percent.

2.2.6.2 Ecological Risk Assessment

Three separate ERAs were prepared for IA-H1, one for each of the exposure areas. The ERA for the Containment Area consisted of a comparison to screening benchmarks. For the Upland Areas and the Non-Tidal Wetland Areas, a combined screening-level and baseline ERA was conducted for each area. The approach for the screening-level ERA corresponds to Steps 1 and 2 of the eight-step Ecological Risk Assessment Process for Superfund (EPA, 1997). The approach for the baseline ERA corresponds to Steps 3 through 8 of the EPA guidance document (1997). The baseline ERA was performed to further refine the conclusions of the screening-level assessment to determine whether the level of risk at the site is acceptable.

Containment Area

A comparison to ecological screening benchmarks was performed for the Containment Area. Since containment is the presumptive remedy for the Containment Area, a comparison to screening benchmarks was considered adequate to support decisions for this remedial alternative. The screening level ERA for the Containment Area is based on the most conservative exposures that are expected to occur, including direct contact with contaminated soil by plants and soil-dwelling organisms, incidental ingestion of contaminated soil by birds and mammals while grooming, eating, or foraging, and the ingestion of contaminants after uptake of constituents into sources of food. Analytical data for the Containment Area was screened against acceptable and conservative risk-based ecological screening benchmark values to identify the potential for ecological impacts. Screening benchmark values used in the evaluation of the Containment Area

included Ecological Soil Screening Levels (EPA, 2003), Oak Ridge National Laboratory On-Line Risk Assessment Information System (ORNL RAIS) ecological screening levels (ORNL RAIS, 2004), and EPA Region 5 RCRA Ecological Screening Levels (EPA, 2003). The range of detected concentrations in all soils (i.e., 0 to 10 feet bgs) was compared to the most conservative screening values identified from these sources.

In the Containment Area, numerous metals, PAHs, phthalates, PCBs, and VOCs exceed ecological screening levels for protection of plants, soil invertebrates, and wildlife by more than one order of magnitude. Based on these exceedances, a significant and immediate risk to ecological receptors exists for the Containment Area. Since a multilayer cap will be installed on the Containment Area under the presumptive remedy alternative, the ecological effects of these chemicals were not evaluated further.

Upland Areas

A combined screening-level and baseline ERA was prepared for the Upland Areas. Field-measured soil, groundwater, and tissue (i.e., plant, earthworm, and small mammal) data collected for the Onshore ERA completed by TtEMI (2002) was used in the ERA for the Upland Areas.

The assessment endpoints identified for habitats within the Upland Areas includes the protection of:

- upland plant communities
- communities of soil-dwelling organisms
- populations of herbivorous mammals
- populations of insectivorous mammals
- populations of passerine birds
- populations of raptors
- populations of large carnivorous mammals

Direct comparison to media-based effects benchmarks is used to measure exposure of plants and soil-dwelling organisms. Food-chain modeling is used to measure exposure of vertebrate receptors in the ERA. The ingestion of prey and incidental ingestion of soil represent the primary

routes of exposure to the Upland Areas receptors; consumption of water from the Non-Tidal Wetland Areas is also considered. The ecological HQ method is used to quantify risk from food chain exposure. For the ecological HQ method, the potential risk posed to target receptors is assessed by comparing estimated daily intake with TRVs. Five vertebrate species (two birds and three mammals) were chosen as representative receptors for food-chain analysis:

- California vole *(Microtus californicus)*
- ornate shrew *(Sorex ornatus)*
- western meadowlark *(Sturnella neglecta)*
- northern harrier *(Circus cyaneus)*
- gray fox *(Urocyon cinereoargenteus)*

Two of the species listed above represent guilds of upper trophic level predators common in the habitats within the Upland Areas of Mare Island. The top predators include raptors (represented by the northern harrier) and large carnivorous mammals (represented by the gray fox). Small herbivorous and insectivorous mammals (represented by the California vole and ornate shrew) and passerine birds (represented by the western meadowlark) are also included in the food-chain analysis.

For the purposes of the ERA, both screening-level and baseline exposure assumptions were used to estimate exposure doses and risk. The estimate of risk expressed as a screening-level analysis is based on reasonably conservative exposure assumptions, such as maximum exposure point concentrations and 100 percent site use. The use of screening-level assumptions represents a worst-case scenario for the areas of concern. The baseline exposure assumptions represent a more reasonable scenario for the areas of concern. For each receptor, only those chemicals of potential ecological concern (COPECs) with a low TRV-based HQ greater than 1 under the screening-level analysis were evaluated in the baseline analysis. The baseline risk is based on adjusting the exposure point concentration and the site use factor to more reasonable assumptions.

The baseline risk analysis indicates that exposure to dioxins, dichlorodiphenyldichloroethane (DDD), PCBs, benzo(a)pyrene, aluminum, arsenic, cadmium, chromium, copper, lead,

manganese, nickel, selenium, vanadium, and zinc in the Upland Areas soil pose a risk to Upland Areas receptors. Aluminum in soil poses a significant or immediate risk to the California vole, ornate shrew, and western meadowlark. Dioxins and vanadium in soil pose a significant or immediate risk to the ornate shrew and chromium poses a significant or immediate risk to the western meadowlark. There is a potential for risk to the California vole exposed to nickel and vanadium; a potential risk to the western meadowlark exposed to dioxins, cadmium, copper, lead, nickel, selenium, zinc, DDD, and benzo(a)pyrene; a potential risk to the northern harrier exposed to PCBs and lead; a potential risk to the gray fox exposed to PCBs, aluminum, and selenium; and a potential risk to the ornate shrew exposed to arsenic, cadmium, copper, lead, manganese, nickel, selenium, and zinc. While aluminum, arsenic, cadmium, chromium, manganese, nickel, vanadium, and benzo(a)pyrene in soil in the Upland Areas do pose an ecological risk, the metal contaminants may be present at ambient/background levels in most cases. Aluminum was not considered further since it is only considered to be toxic to ecological receptors if the pH is less than 5.5, which is not the case at this site.

Non-Tidal Wetland Areas

A combined screening-level and baseline ERA was prepared for the Non-Tidal Wetland Areas. Field-measured sediment, surface water, and tissue (i.e., plants, pickleweed, benthic invertebrates, amphibians, and small mammals) data collected for the Onshore ERA (TtEMI, 2002) was used in the ERA for the Non-Tidal Wetland Areas.

The assessment endpoints identified for the habitats within Non-Tidal Wetland Areas includes protection of:

- plant communities
- communities of benthic invertebrates
- populations of small mammals (or protection of individuals, in the case of the salt marsh harvest mouse)
- populations of shorebirds
- populations of wading birds
- populations of waterfowl
- populations of raptors
- populations of large carnivorous mammals

Direct comparison to media-based effects benchmarks is used to measure exposure of wetland plants and sediment-dwelling organisms. Food-chain modeling is used to measure exposure of vertebrate receptors in the ERA. The ingestion of prey and incidental ingestion of sediment and surface water represent the primary routes of exposure to the Non-Tidal Wetland Areas receptors. The HQ method is used to quantify risk from food chain exposure. For the HQ method, the potential risk posed to target receptors is assessed by comparing estimated daily intake with TRVs. Four vertebrate species (three birds and one mammal) were chosen as representative receptors for food-chain analysis to evaluate risks to small mammals, shorebirds, waterfowl, and wading birds:

- salt marsh harvest mouse *(Reithrodontomys raviventris)*
- killdeer *(Charadrius vociferous*)
- mallard *(Anas platyrhynchos)*
- great blue heron *(Ardea herodias)*

The two upper trophic level predators evaluated for the Upland Areas (northern harrier and gray fox) were also chosen for the food-chain analysis for the Non-Tidal Wetland Areas as these receptors may roam throughout both habitats.

Two of the four species listed above represent guilds of upper trophic level predators common in the Non-Tidal Wetland Areas of Mare Island. These guilds include insectivorous birds (represented by the killdeer) and carnivorous birds (represented by the great blue heron). The salt marsh harvest mouse is a herbivorous mammal that feeds primarily on pickleweed and saltgrass. The salt marsh harvest mouse was selected for food-chain analysis because it is a federal and state endangered species that occurs in the area; its endangered status requires that individual mice be protected. Inhalation of VOCs released from soil and groundwater was also evaluated for this sensitive species. Waterfowl (represented by the mallard) were included in the food-chain analysis because they are protected under the Migratory Bird Treaty Act (MBTA) and are potential prey for raptors.

For the purpose of the ERA, both screening-level and baseline exposure assumptions were used to estimate exposure doses and risk. The estimate of risk expressed as a screening-level analysis

is based on reasonably conservative exposure assumptions, such as maximum exposure point concentrations and 100 percent site use. The use of screening-level assumptions represents a worst-case scenario for the area of concern. The baseline exposure assumptions represent a more reasonable scenario for the area of concern. For each receptor, only those COPEC with a low TRV-based HQ greater than 1 under the screening-level analysis were evaluated in the baseline analysis. The baseline risk is based on adjusting the exposure point concentration and the site use factor to more reasonable assumptions.

The baseline analysis indicates that exposure to PCBs, benzo(a)pyrene, aluminum, antimony, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, vanadium, and zinc in soil pose a risk to ecological receptors within the Non-Tidal Wetland Areas. PCBs in sediment and/or prey pose a significant or immediate risk to the gray fox, the killdeer, and the salt marsh harvest mouse. Chromium, manganese, mercury, and selenium also pose a significant or immediate risk to the killdeer, while aluminum, antimony, lead, manganese, nickel, vanadium, and zinc pose a significant or immediate risk to the salt marsh harvest mouse. Lead in sediment and/or prey tissue poses a potential risk to the mallard (breeding and non-breeding), northern harrier, great blue heron, and killdeer. Benzo(a)pyrene, aluminum, barium, cadmium, copper, nickel, and zinc also pose a potential risk to the killdeer. PCBs pose a potential risk to the northern harrier and great blue heron and aluminum and selenium pose a potential risk to the gray fox. While aluminum, barium, cadmium, chromium, copper, manganese, mercury, nickel, vanadium, zinc, and benzo(a)pyrene in sediment in the Non-Tidal Wetland Areas do pose an ecological risk, the metal contaminants may be present at ambient/background levels in most cases. Aluminum was not be considered further since it is only considered to be toxic to ecological receptors if the pH is less than 5.5, which is not the case at this site.

2.2.7 Applicable or Relevant and Appropriate Requirements

The basis for applicable or relevant and appropriate requirements (ARARs) is cited in Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments Reauthorization Act of 1986 (SARA), which requires Superfund-financed enforcement and federal facility remedial actions to comply

with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility citing laws, unless such standards are waived. "For the purpose of identification and notification of promulgated state standards, the term *promulgated* means that the standards are of general applicability and are legally enforceable" (EPA, 1994).

> "Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility citing law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and those that are more stringent than federal requirements may be applicable" (EPA, 1994).

However, ARARs not identified in a timely manner may still be considered.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility citing law that, while not applicable to a hazardous substance pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to a particular site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be relevant and appropriate. However, ARARs not identified in a timely manner may still be considered.

As defined in the Code of Federal Regulations (CFR) Title 40, Section 300.400[g][3], the "To Be Considered" (TBC) category "consists of advisories, criteria, or guidance developed by the EPA, other federal agencies, or states that may be useful in developing CERCLA remedies. Use of TBC is discretionary rather than mandatory as opposed to the use of ARARs, which is mandatory.

Pursuant to EPA guidance (EPA, 1988), ARARs are generally divided into three categories: chemical-specific, location-specific, and action-specific requirements. This classification was

developed to aid in the identification of ARARs; however, some ARARs do not fall precisely into one group or another. ARARs are identified on a site basis for potential remedial actions where CERCLA authority is the basis for cleanup. The identification and evaluation of the potential ARARs for IA-H1 are presented in detail in Appendix A.

2.2.8 Conclusion

In general, all of the IA-H1 subareas described in the IA-H1 Final RI (Containment Area, Upland Areas, and Non-Tidal Wetland Areas) were recommended to be carried forward to the FS stage. The information accumulated for the site, and presented in the RI, is combined with ARARs to generate remedial action objectives in the next section.

3. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section presents the remedial action objectives (RAOs) and general response actions (GRAs) developed for the Containment Area and the Upland and Non-Tidal Wetland Areas outside the Containment Barrier, within Investigation Area H1 (IA-H1).

3.1 REMEDIAL ACTION OBJECTIVES

RAOs are medium-specific goals for protecting human health and the environment. Each RAO should specify the contaminant(s) and media of concern, the exposure pathway, and an acceptable contaminant concentration or range of concentrations for each exposure pathway. RAOs include both an exposure pathway and a contaminant concentration in a given media because protectiveness may be achieved in two ways: by limiting or eliminating the exposure pathway and/or by reducing contaminant concentrations. RAOs developed for the protection of environmental receptors typically seek to restore or preserve a resource, and therefore, these RAOs should apply target contaminant levels, wherever feasible, to each medium of interest.

The Office of Solid Waste and Emergency Response Directive 9355.7-04 states that RAOs should reflect reasonably anticipated future land use. The Mare Island Final Reuse Plan (City of Vallejo, California, 1994) establishes the future land use at IA-H1 as open space/recreational. The Non-Tidal Wetland Areas (Wetlands A, B, C, and D) will remain habitat for the salt marsh harvest mouse (an endangered species), shore birds, migratory waterfowl, and other wildlife.

The Containment Area RAOs rely on eliminating exposure pathways based on the presumptive remedy or on total removal. RAOs for the Upland and Non-Tidal Wetland Areas outside the Containment Barrier follow a development of risk-based exposure levels for chemicals of concern (COCs) and evaluation of exposure pathways.

3.1.1 Containment Area

The objectives for the presumptive remedy at landfill sites include containment of the landfill mass, measures to collect and manage landfill gas (if present), and collect and manage landfill leachate affecting groundwater quality (EPA, 1996).

3.1.1.1 Landfill Refuse Remedial Action Objective

The primary exposure pathways for landfill refuse and contaminated media are dermal contact, ingestion, and inhalation of compounds. Surface exposure is currently controlled with a soil cover. Erosion by wind and rain could potentially expose landfill refuse and contaminated media, thereby potentially enhancing risks of ingestion and inhalation of materials of concern. In addition, erosion could result in migration of contaminants off site.

The general RAO for the Containment Area is to protect human and ecological receptors from exposure to landfill refuse and soil contamination by eliminating exposure pathways and contaminant migration.

3.1.1.2 Groundwater Remedial Action Objective

Groundwater at IA-H1 is not suitable for human consumption due to high levels of dissolved solids and low production rates as evaluated and confirmed by the Regional Water Quality Control Board (RWQCB) (RWQCB, 2004). The landfill refuse and contaminated soil are therefore not a threat to drinking water. However, migration of the contaminated groundwater may have an adverse ecological effect on target receptors due to exposure through ingestion, inhalation, or dermal contact (WESTON, 2004a).

The RAO for groundwater is to minimize the effects of landfill refuse and soil contaminants on groundwater quality (e.g. infiltration with rainwater) and eliminate migration of contaminated groundwater to potential off-site receptors.

3.1.1.3 Landfill Gas Remedial Action Objective

The landfill gas investigations indicate that gases, including methane, carbon dioxide, and volatile organic compounds (VOCs) are being generated at the interim status RCRA Landfill.

The general RAO for landfill gas is to protect human and ecological receptors by minimizing exposure pathways and gas migration.

3.1.2 Upland and Non-Tidal Wetland Areas outside the Containment Barrier

The identification of exposure pathways and receptors is an important component in developing RAOs, because human health and environmental protection may be achieved by reducing exposure to contaminants. The baseline Human Health Risk Assessments (HHRAs) evaluated carcinogenic and noncarcinogenic risks associated with exposure to chemical contaminants in the Upland and Non-Tidal Wetland Areas of IA-H1 under a "No Action" alternative, i.e., in the absence of remedial (corrective) action. The Ecological Risk Assessments (ERAs) for the Upland and Non-Tidal Wetland Areas of IA-H1 evaluated adverse effects to ecological receptors.

Based on current and potential future site conditions, the baseline HHRA for IA-H1 evaluated potential exposed populations, including child/adolescent recreators and construction workers who would be present during redevelopment construction. Potential exposure to site soils (surface and subsurface) via ingestion, dermal contact, and inhalation were estimated individually for child recreational users and an adult construction worker. While different exposure assumptions were used for each age group, the same toxicity criteria (i.e., slope factors and reference doses) were applied to all population subgroups evaluated. For groundwater, VOCs were evaluated because the only identified exposure pathway to groundwater at IA-H1 is inhalation of vapors. Surface water exposure was only evaluated for recreational users as this receptor group is expected to be exposed more frequently than other receptors.

Leaching of soil contaminants to groundwater is another exposure pathway that must be evaluated in the development of RAOs. Because the mechanisms differ for exposure from direct

contact and migration to groundwater, separate RAOs are developed to evaluate these pathways. Under this exposure pathway, COCs are assumed to leach from soil into groundwater.

The baseline ERA for the Upland and Non-Tidal Wetland Areas of IA-H1 evaluated adverse effects to representative ecological receptors inhabiting these areas. Because ecological receptors differ by habitat and by feeding type, the baseline ERA evaluated several feeding guilds within each habitat type. Food-chain modeling was used to evaluate risk to ecological receptors from site-specific chemical stressors. The ingestion of prey and incidental ingestion of soil represent the primary routes of exposure to the Upland Areas receptors. The ingestion of prey and the incidental ingestion of sediment and surface water represent the primary routes of exposure to the Non-Tidal Wetland Areas receptors. Representative receptor species evaluated for the Upland Areas included mammalian and avian carnivores (gray fox and northern harrier) consuming small mammal tissue; mammalian and avian insectivores (ornate shrew and western meadowlark) consuming earthworms; and a herbivorous small mammal (California vole) consuming upland plants. Representative receptor species evaluated for the Non-Tidal Wetland Areas included mammalian and avian carnivores (gray fox and northern harrier) consuming small mammal tissue; the omnivorous great blue heron consuming small mammals and amphibians; an insectivorous bird (killdeer) consuming aquatic invertebrates; an avian omnivore consuming wetland plants and aquatic insects (breeding mallard); the herbivorous non-breeding mallard consuming wetland plants; and a herbivorous small mammal of special concern (salt marsh harvest mouse) consuming pickelweed.

The following subsections summarize the development of RAOs for the Upland and Non-Tidal Wetland Areas of IA-H1, including the identification of COCs, development of preliminary remediation goals (PRGs) for each receptor group/exposure pathway, development of hot spot screening criteria, and selection of RAOs.

3.1.2.1 Identification of Chemicals of Concern for Areas outside the Containment Barrier

Numerical PRGs were developed for those chemicals detected in soil and sediment that pose a risk to human health and the environment. These chemicals are the COCs for this site. The list of COCs differs based on the receptor and exposure pathway considered, as described below.

3.1.2.1.1 Outlier Chemicals of Concern

Prior to performing the HHRA and ERA, all soil data from the Upland Areas and all sediment data from the Non-Tidal Wetland Areas were screened for outliers using statistical methods (e.g., using box plots, probability plots) and professional judgment. The box plots were used to determine near and far outliers in the datasets, and the probability plots were used to visually evaluate the datasets. The methodology used to identify outliers is described in detail in the Final RI for IA-H1 (WESTON, 2005a).

Chemical concentrations within the area-wide datasets that were determined to be outliers were omitted from the soil and sediment datasets evaluated in the risk assessments. All chemicals with at least one concentration identified as an outlier were automatically considered to be COCs for both human and ecological receptors. Chemicals for which at least one outlier concentration was identified in Upland Areas soil include antimony, arsenic, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, tin, vanadium, zinc, total polychlorinated biphenyls (PCBs), benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and total petroleum hydrocarbons as motor oil (TPH-m). Chemicals for which at least one outlier concentration was identified in Non-Tidal Wetland Areas soil and sediment include aluminum, arsenic, barium, chromium, copper, lead, manganese, nickel, tin, zinc, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, and TPH-m. The Upland and Non-Tidal Wetland Areas outlier concentrations are presented in Tables 3-1a and 3-1b, respectively.

3.1.2.1.2 Human Health Chemicals of Concern

The HHRA for the Upland and Non-Tidal Wetland Areas of IA-H1 characterized potential cancer and adverse noncancer health effects associated with chemicals of potential concern (COPCs) within various environmental media at the site. The HHRA accounts for potential multi-chemical exposure that may occur at the site by summing the cancer risks and/or the Hazard Indexes (HIs) for all COPCs. COCs were identified as chemicals with individual cancer risk estimates greater than one-in-one million for an individual or target organ HI greater than 1. Human health COCs identified for the Upland Areas of IA-H1 include arsenic, total PCBs, and benzo(a)pyrene in soil. The only human health COC identified for the Non-Tidal Wetland Areas is arsenic in soil/sediment and surface water. Additionally, a California Environmental Agency Department of Toxic Substance Control (DTSC) lead risk assessment tool, LEADSPREAD, was used to estimate blood lead concentrations resulting from exposure to lead via dietary intake, drinking water, soil and dust ingestion, inhalation, and dermal contact. Since the exposure point concentration (EPC) for lead exceeded the 95th percentile preliminary remediation goal (PRG) for lead as determined by LEADSPREAD, lead was retained as a COC for both the Upland and Non-Tidal Wetland Areas.

3.1.2.1.3 Ecological Chemicals of Concern

The identification of chemicals of potential ecological concern (COPECs) was used to focus the baseline ERA on specific chemicals that may present a risk to ecological receptors based on bioaccumulation potential or toxicity. The potential risk posed to target receptors was assessed by comparing estimated daily intake with low and high toxicity reference values (TRVs). During the risk characterization stage of the baseline ERA, COPECs were defined in qualitative terms as posing (1) little or no risk, (2) significant and immediate risk, or (3) potential risk. A chemical is considered to pose little or no risk if the Hazard Quotient (HQ) based on the low TRV does not exceed 1. A chemical is considered to potentially pose significant and immediate risk if the HQ based on the high TRV exceeds 1 or if the HQ based on the low TRV exceeds 1 for special concern species (i.e., threatened and endangered species). A chemical is considered to pose a potential risk if the HQ based on the low TRV exceeds 1 but the HQ based on the high TRV does not exceed 1. No further action will be considered for COPECs that pose little or no risk.

COPECs that pose potential risk, or significant or immediate risk, are further evaluated as chemicals of ecological concern (COECs).

Upland Areas

The baseline ERA concluded that there is a significant or immediate risk (HQ greater than 1 using the high TRV) to ecological receptors exposed to dioxins, aluminum, chromium, and vanadium in soil and/or prey, and a potential risk (HQ greater than 1 using the low TRV) to ecological receptors exposed to dichlorodiphenyldichlorethane (DDD), dioxin-like PCBs, benzo(a)pyrene, arsenic, cadmium, copper, lead, manganese, nickel, selenium, and zinc in soil and/or prey. While aluminum, arsenic, cadmium, chromium, manganese, nickel, and vanadium, in soil in the Upland Areas have been determined to pose an ecological risk, these contaminants are present at ambient/background levels in soil. Aluminum is not considered a COEC since it is toxic to ecological receptors only at a pH less than 5.5, which is not the case at this site.

In summary, the COECs for the Upland Areas include dioxins, PCBs, DDD, benzo(a)pyrene, arsenic, cadmium, chromium, copper, lead, manganese, nickel, selenium, vanadium, and zinc. Arsenic, cadmium, chromium, manganese, nickel, and vanadium will be evaluated further as chemicals posing an ecological risk at ambient/background concentrations and will be evaluated for remediation only at locations that contain one or more of the other identified COECs (i.e., dioxin, PCBs, DDD, benzo(a)pyrene, copper, lead, selenium, and zinc).

Non-Tidal Wetland Areas

In the Non-Tidal Wetland Areas, the baseline ERA concluded that there is an immediate and significant risk (HQ greater than 1 using the high TRV or HQ greater than 1 using the low TRV for sensitive species) to ecological receptors exposed to PCBs, antimony, chromium, lead, manganese, mercury, nickel, selenium, vanadium, and zinc in sediment and/or prey, and a potential risk (HQ greater than 1 using the low TRV for non-sensitive species) to ecological receptors exposed to benzo(a)pyrene, barium, cadmium, and copper in sediment and/or prey.

While aluminum, barium, cadmium, chromium, copper, manganese, mercury, nickel, vanadium, zinc, and benzo(a)pyrene in soil/sediment in the Non-Tidal Wetland Areas do pose an ecological risk, the metal contaminants listed are present at ambient/background levels in soil. Also, aluminum is not considered a COEC since it is toxic to ecological receptors only at a pH less than 5.5, which is not the case at this site.

In summary, the COECs in the Non-Tidal Wetland Areas are PCBs, benzo(a)pyrene, antimony, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, vanadium, and zinc. Barium, cadmium, chromium, copper, manganese, mercury, nickel, vanadium, and zinc will be evaluated further as chemicals posing an ecological risk at ambient/background concentrations and will be evaluated for remediation only at locations that contain one or more of the other identified COECs (i.e., PCBs, antimony, lead, and selenium).

3.1.2.1.4 Soil Chemicals Posing a Potential Threat to Groundwater

Because the site-specific risk assessment did not identify any surface water risk other than arsenic, the threat to groundwater was determined to be free product, or TPH. Also, any boring location where free product was identified is considered a threat to groundwater.

3.1.2.2 Development of Preliminary Site-specific Cleanup Goals

Site-specific cleanup goals are the acceptable levels for each outlier chemical, and for each COC, for every receptor group/exposure route (i.e., humans, threat to groundwater, and ecological receptors). In the Final RI (WESTON, 2005a), screening levels were initially derived for each COPC to illustrate the nature and extent of contamination at the site. The screening levels developed in the Final RI (WESTON, 2005a) were based on the most conservative (i.e., most stringent) risk-based or effects-based value for each chemical and were primarily obtained from literature sources. The screening levels developed in the RI are revised in this section of the Feasibility Study (FS), using site-specific information from the HHRA, the threat to groundwater assessment, and the baseline ERA. The numerical site-specific cleanup goals serve as cleanup levels protective of human health and the environment under an anticipated future recreational

land use scenario. Site-specific cleanup goals are selected from several risk-based concentrations (RBCs) for protection of human health, threats to groundwater, and ecological impact. The RBCs are intermediate concentrations developed for a specific receptor group, exposure route, and/or target risk level. Numerical site-specific cleanup goals are the most stringent of the RBCs for each receptor group/exposure pathway.

3.1.2.2.1 Soil and Sediment Preliminary Site-Specific Cleanup Goals

SSCGs were developed for each outlier chemical and human health COC identified in soil and sediment. The site-specific cleanup goals developed for this FS are based on the most conservative (i.e., most stringent) of the RBCs for each receptor group based on both carcinogenic and noncarcinogenic health effects. RBCs for soil and sediment were developed based on a carcinogenic risk of $1x10^{-6}$ and/or a noncancer HQ of 1 for combined exposure via ingestion, dermal contact, and inhalation of COCs by a child recreational user and a construction worker. RBCs were determined using the risk equations and exposure parameters presented in the HHRA to back-calculate the contaminant concentration that results in a cancer risk of $1x10^{-6}$ and/or a noncarcinogenic HQ value of 1. The human health RBC equations are based on EPA's Risk Assessment Guidance for Superfund (EPA, 1998) guidance and are presented in the HHRA (Final RI for IA-H1 [WESTON, 2005a], Appendix I). The development of the RBCs is included as Tables 3-2a through 3-2d. LEADSPREAD (DTSC, 1990) was used to develop a 95th percentile RBC for lead (Table 3-2e). The human health site-specific cleanup goals identified for the human health COCs are presented in Table 3-3.

3.1.2.2.2 Surface Water Preliminary Remediation Goals

Arsenic is the only human health COC for surface water within the Non-Tidal Wetland Areas. The risk equations presented in the HHRA were used to back-calculate the arsenic concentration resulting in a cancer risk of $1x10^{-6}$. The surface water RBC for arsenic based on a $1x10^{-6}$ cancer risk level is 8.8 micrograms per liter (µg/L).

Threat to Groundwater Site-Specific Remediation Goals

The remaining beneficial use for groundwater as defined in the San Francisco Basin Plan for the San Francisco Bay Basin (Cal EPA 2004) in the Upland and Non-Tidal Wetland areas is potential discharge to wetlands. Groundwater discharge to wetlands would be captured at this relatively mature site in the site-specific risk assessment. The risk assessment of surface water in the wetlands would account for any mixing with groundwater and is a much more direct analysis than back calculated models. The surface water risk assessment illustrated that elevated arsenic levels were the only surface water threat. The surface water levels of arsenic are attributed to the high levels of ambient/background arsenic at Mare Island. Free product (petroleum) has been observed in borings in soils at IA-H1 and is considered to be a threat to groundwater. The threat to groundwater SSCGs are presented in Table 3-4.

Ecological Site-Specific Cleanup Goals

Ecological risk-based SSCGs were developed for chemicals considered to be data outliers and for chemicals that pose a significant or immediate and a potential risk to ecological receptors in the baseline ERA. Ecological RBCs were developed for Upland Areas soil and Non-Tidal Wetland Areas sediment, with separate ecological RBCs determined for each receptor group in these habitats. The following general equation was used to develop the ecological RBCs for each ecological receptor and each COEC:

$$RBC_j = \frac{TRV_j \times HQ_j}{\left(\left[P_s \times FIR \right] + \left[\sum_{i=1}^{N} \left(T_{ij} \right) \times P_i \times FIR \right] \right) \times SUF}$$

where:

HQ_j = Hazard quotient for contaminant (j) (unitless)

RBC_j = Risk-based concentration of contaminant (j) in soil or sediment (milligram per kilogram [mg/kg] dry weight)

N = Number of different biota types in diet

T_{ij} = Soil-to-biota bioaccumulation factor (BAF) (units- dry weight to dry weight) for contaminant (j) for food type (i)

P_i = Proportion of biota type (i) in diet

FIR = Food ingestion rate (kilogram [kg] food [dry weight]/ kg body weight (BW) [wet weight] /day)

TRV_j = Toxicity reference value of contaminant (j) (mg/kg BW/day)

P_s = Soil ingestion as proportion of diet

SUF = Site use factor

The parameters used in developing RBCs are described in the following subsections.

Intake Parameters

The intake parameters (i.e., FIR, P_i, P_s, BW, and SUF) are the same as used in the baseline ERA, as described in Section 2.2.6.2. Reduced site use factors for the northern harrier, gray fox, and mallard are based on individual species home range as presented in the baseline ERA.

Bioaccumulation Factors

Tissue and substrate data collected from Mare Island as part of the Onshore ERA (TtEMI, 2002) were used to determine site-specific BAFs for the COEC. Tissues of plants, invertebrates, and vertebrates within IA-H1 were analyzed for chemical residues. A summary of the tissue collection and the calculation strategy for the BAFs is presented in Table 3-5.

A BAF is calculated as follows:

$$BAF = \frac{Tissue\ Concentration}{Substrate\ Concentration}$$

Only tissue, soil, and sediment samples collected during the Onshore ERA (TtEMI, 2002) from the Upland and Non-Tidal Wetland Areas within IA-H1 were considered in the development of BAFs. First, an individual BAF was calculated for each discrete sample location and then a representative average BAF was calculated for each chemical for each tissue type, where

possible. The 95 percent UCL on the mean was used as the representative average BAF, where the 95 percent UCL was calculated using EPA ProUCL Version 3 software. Individual BAFs were calculated by dividing the concentration of a chemical in a tissue sample by the average concentration of the chemical in a substrate sample (soil or sediment, as appropriate) from the same location (see Table 3-5). If a 95 percent UCL could not be calculated because of small sample size, the maximum BAF was used. The BAF development is presented as Appendix B of this document. The BAFs for Upland Areas tissue are presented in Table 3-6a and the BAFs for Non-Tidal Wetland Areas tissue are presented in Table 3-6b.

Hazard Quotient

The target HQ for ecological RBC development is equal to 1. An HQ less than 1 indicates the contaminant alone is unlikely to cause adverse ecological effects (EPA, 1997).

Toxicity Reference Value

The wildlife TRV is defined as follows: *Dose above which ecologically relevant effects might occur to wildlife species following chronic dietary exposure and below which it is reasonably expected that such effects will not occur (*EPA, 2003). Ecological RBCs were developed using both low and high TRVs, as presented in the baseline ERA (WESTON, 2005a). The low TRV is consistent with a chronic no-effect level; the no-effect level is the highest dose at which no effect to the test organism was observed. The high TRV is consistent with an effect level. An effect level is the dose at which a specific biological effect was seen in the laboratory test organism. High TRVs were selected from approximately the middle range of all sublethal effects for a particular chemical.

Ecological Risk-Based Concentrations

The ecological RBCs for each receptor group are presented in Tables 3-7a through 3-7e for the Upland Areas ecological receptors and Tables 3-8a through 3-8e for the Non-Tidal Wetland Areas ecological receptors.

Determination of Ecological Site-Specific Cleanup Goal

Ecological-based site-specific cleanup goals are acceptable concentrations for each COEC and each habitat. The most stringent of the calculated ecological RBCs for each habitat were selected as the ecological site-specific cleanup goals for each COEC in that habitat. Ecological site-specific cleanup goals are summarized in Tables 3-9a and 3-9b for the Upland and Non-Tidal Wetland Areas, respectively. Only the RBCs based on the low TRV are presented in Tables 3-9a and 3-9b.

Selected SSCG for each Exposure Area

The final site-specific cleanup goals for each chemical and exposure area selected as the most stringent of the developed site-specific cleanup goals for human health, threats to groundwater, and ecological exposures are presented in Tables 3-10a and 3-10b for the Uplands and Non-Tidal Wetlands Areas, respectively.

3.1.2.3 Development of Hot Spot Screening Criteria

Hot spot screening criteria are developed based on risks to human health, threats to groundwater, and risks to ecological receptors. Hot spot screening criteria will be used to determine hot spot locations requiring remediation and as a screening value used in the field during remediation for comparison of confirmation sampling results.

Human Health Hot Spot Screening Criteria

Screening criteria based on human health risks that are used to identify hot spot areas in IA-H1 were developed similarly to the method used for human health site-specific cleanup goal development, using the risk equations presented in the HHRA and back-calculating a chemical concentration to represent a hot spot screening level. Hot spot screening levels for human health risk include chemical concentrations that result in either a $1x10^{-5}$ cancer risk level or a noncarcinogenic HQ value of 1. Note that outside the containment area no individual chemical exceeded an HI of 1 and the cumulative HI for all risk scenarios was below 1. With arsenic excluded, a sample location is defined as a hot spot for human health if it contains contaminants

exceeding a cancer risk of $1x10^{-5}$ or a cumulative HI of 1 for the recreational child. When arsenic is included, a sample location is defined as a hot spot if it contains contaminants exceeding a cancer risk of $1x10^{-4}$ or a cumulative HI of 1. A summary of the hot spot screening criteria based on human health risks is presented in Table 3-11.

Threat to Groundwater Hot Spot Screening Criteria

Boring logs were used to determine areas that exhibited oil/free product. Oil/free product was observed in several soil borings located near the former oil sumps and impoundment areas and in other areas of Installation Restoration (IR) 01. All locations in which oil/free product was observed on the boring log were identified as soil leaching to groundwater hot spots. A summary of the hot spot screening criteria based on threats to groundwater is presented in Table 3-12.

Ecological Hot Spot Screening Criteria

Screening criteria used to identify hot spot areas in IA-H1 were developed similarly to the method used in ecological site-specific cleanup goal development, using the risk equations presented in the baseline ERA and back-calculating a chemical concentration to represent a hot spot screening level. Ecological hot spot screening levels were developed based on chemical concentrations that correspond to HQs of 1, 3, 5, and 10 for adverse effects using the high TRV. A summary of the hot spot screening criteria based on ecological risks are presented in Tables 3-13a and 3-13b for the Upland and Non-Tidal Wetland Areas, respectively.

Selected Hot Spot Criteria for each Exposure Area

The final hot spot screening level for each chemical and exposure area is presented as the most stringent of the developed hot spot screening levels for protection of human health, threat to groundwater, and ecological impact.

Hot spot screening levels were developed for four exposure intervals: surface soil (0 to 2 feet below ground surface (bgs)); shallow subsurface soils (2 to 4 feet bgs); subsurface soils (4 to 10 feet bgs); and deep subsurface soils (depths greater than 10 feet bgs). Ecological receptors other than the gray fox, which is a burrowing mammal, are only expected to be exposed to surface soil

(upper 2 feet of soil). The gray fox may burrow to depths up to 4 feet (however the gray fox is currently trapped on Mare Island along with other potential salt marsh harvest mouse predators), and humans may be exposed to soil from depths up to 10 feet in the event of earthmoving activities at the site. Threats to groundwater were the only criteria considered for depths greater than 10 feet bgs.

These hot spots have been calculated based on current site characteristics; the 2 foot soil cover will add to the overall protectiveness and residual risk has been calculated to include the addition of the two-foot soil cover. Note also that all proposed alternatives include restrictions and notifications required for any digging at the site and that based on the proposed site use it would be unlikely that future excavation would be allowed.

The final hot spot screening levels for the various exposures are presented in Tables 3-14a through 3-14g for the Upland Areas and Tables 3-15a and 3-15f for the Non-Tidal Wetland Areas. Tables 3-14a through 3-14d for the Upland Areas and Tables 3-15a through 3-15d for the Non-Tidal Wetland Areas present various hot spot screening levels for surface soil exposure based on multiples of the ecological hot spot screening level (i.e., based on HQs of 1, 3, 5, and 10). Table 3-14e presents the shallow subsurface hot spot screening level for soils in the Upland Areas. Tables 3-14f and 3-15e present the hot spot screening level for subsurface soil in the Upland and Non-Tidal Wetland Areas, respectively. Tables 3-14g and 3-15f present hot spot screening levels for deep subsurface soil in the Upland and Non-Tidal Wetland Areas, respectively.

Several of the chosen hot spot levels for the various alternatives defaulted to ambient/background values due to threats to either human or ecological receptors because most hot spot screening criteria are lower than ambient/background. For the Upland Areas an average threshold is used to guide the remediation. The average threshold is compared to existing concentration results at individual locations to identify hot spots for excavation and the subsequent confirmation sample results to determine if further excavation is required. In the Non-Tidal Wetland Areas in cases where chosen hot spot levels defaulted to ambient/background values, two hot spot levels are proposed based on an average threshold and an upper threshold value. The average threshold represents the acceptable ecological RBC. The upper threshold is a

"do-not-exceed" hot spot level for discrete samples. For metals where the hot spot screening level is presented in Tables 3-14a through 3-14d and Tables 3-15a through 3-15d, the average threshold is the value presented as the hot spot screening level in these tables For these same inorganic constituents, the upper threshold is the lowest of the ecological RBCs based on the high TRV and a HQ of 1. Due to the high level of uncertainty associated with the avian TRV for barium, the avian RBCs were not used in selecting the hot spot thresholds. Threshold values are not presented for tin due to the uncertainty associated with the TRVs for this metal, which were based on the organotin, tributyltin oxide. Organotins are more toxic than inorganic tins and have not been detected in non-tidal wetland sediments. All threshold values are presented in Table 3-16.

3.1.2.4 Remedial Action Objectives

Based on the human health and threat to groundwater COCs and the COECs, the exposure pathways and receptors present at this site, and the calculated acceptable constituent level (i.e., the site-specific cleanup goal) for each exposure pathway, the following RAOs were developed for IA-H1 Upland and Non-Tidal Wetland Areas:

Upland Areas

- Reduce exposure via ingestion, direct contact, and inhalation of site soil containing COC concentrations that present an area-wide cancer risk estimate of $1x10^{-5}$ (without the contribution of ambient/background arsenic) or noncarcinogenic adverse health effects resulting in an HI of 1.
- Reduce exposure to COECs present within the soil posing immediate and significant or potential risk to the gray fox, the northern harrier, the western meadowlark, ornate shrew, and California vole.
- Reduce downward migration of soil COCs to the SWBZ underlying IA-H1.
- Reduce migration of COCs present within surface soil in IA-H1 toward the sediment and surface water of the Non-Tidal Wetland Areas of IA-H1.
- Control direct exposure and protect future workers from the extremely low residual risk posed by potential ordinance and explosives (OE) and radiological material in IA-H1.

Non-Tidal Wetland Areas

- Reduce exposure via ingestion, direct contact, and inhalation of site soil containing COC concentrations that present an area-wide cancer risk estimate of $1x10^{-5}$ (without the contribution of ambient/background arsenic) or noncarcinogenic adverse health effects resulting in an HI of 1.
- Reduce exposure to COECs present within the sediment posing immediate and significant or potential risk to the killdeer, great blue heron, the mallard, and the salt marsh harvest mouse.
- Reduce exposure via ingestion of surface water containing COC concentrations presenting an area-wide cancer risk estimate of $1x10^{-5}$ (without the contribution of ambient/background arsenic) to humans at the Non-Tidal Wetland Areas.
- Control direct exposure and protect future workers from the extremely low residual risk posed by potential MEC and radiological material in IA-H1.

3.2 GENERAL RESPONSE ACTIONS

This section provides a general description of the GRAs that may be applicable to the Containment Area and the Upland and Non-Tidal Wetland Areas outside the Containment Barrier.

3.2.1 No Action

The NCP requires that "No Action" be included among the GRAs evaluated in every FS (Code of Federal Regulations, Title 40 [40 CFR], Section 300 430[e][b]) to provide a baseline for comparison against other remedial response actions. Under this GRA, the areas will remain in their current state, and no actions will be conducted to remove, isolate, or remediate the contamination. Under the "No Action" response, long-term monitoring would not be used to assess changes in contaminant concentrations within affected media and no institutional controls would be put into place.

The potential for erosion and other actions that may unearth refuse and contaminated media present an avenue for exposure. The "No Action" GRA does not meet the RAO for soil, landfill gas, or groundwater but is required to be considered to provide a baseline for comparison with other alternatives.

3.2.2 Management and Institutional Controls

Institutional controls are non-engineering measures, usually legal or physical means, of limiting potential exposures to a site or medium of concern. Institutional controls prevent human exposure to the identified COCs, but they do not address reducing the toxicity, mobility, or volume of contamination. Examples of institutional controls cited in the NCP include land access, resource use, and deed restrictions. Institutional controls can also include site monitoring and access restrictions such as fencing.

Management and institutional controls for landfills involve land use restrictions and could include institutional restrictions prohibiting wells from being placed in or around the RCRA/Facility Landfill for groundwater use. These actions may prevent direct contact with the groundwater but would not prevent migration of contaminated groundwater off site. Therefore, management and institutional controls alone would not meet the RAO for groundwater.

Monitoring could be implemented to detect any increase in contamination or movement of contaminated material off site. At this site there is a potential for lateral migration of hazardous materials to adjacent lands, affecting sensitive receptors. Monitoring alone would not meet the RAO for soil.

3.2.3 Containment Actions

Containment actions refer to technologies that isolate contaminants from human and ecological contact. Containment actions are designed to isolate refuse and/or soil contaminants; minimize disturbance to the affected soils; reduce off-site contaminant migration; minimize migration of groundwater; and minimize vapor releases to the atmosphere. Containment limits or controls the migration of contaminants beyond the present area of contamination into adjacent areas, but does not contribute to reducing the toxicity or volume of contamination. These actions are applicable for preventing human and ecological exposures to refuse and contaminated soil and groundwater. Containment actions are the presumptive remedy for landfills of this size and would meet the RAO for soil.

Containment of groundwater may include installing a barrier to prevent migration and/or groundwater collection and removal to reduce the hydraulic head within the barrier. This would prevent contaminated groundwater from moving off site. Because the groundwater does not meet the criteria for beneficial use, the containment of contaminated groundwater meets the RAO.

3.2.4 Removal (Collection) and Disposal

Removal (collection) and disposal involves excavating refuse and soil contaminated above specific clean-up criteria from their existing location to facilitate treatment or disposal actions. Excavation of contaminated soil/sediment is an example of a collection activity. The impacted media can then be treated or disposed of following excavation. However, removal and disposal of material in another landfill would simply move contamination from one area to another. Removal and disposal would meet the RAO for soil.

3.2.5 Treatment

Treatment processes are used to reduce toxicity, mobility, and/or volume of contamination either *in-situ* or *ex-situ*. The treatment may occur with the material left in place or may require the removal of the target materials to perform a function that alters the chemistry of the contaminant molecule by physical/chemical, thermal, or biological processes. Examples of treatment include stabilization, biological treatments, and treatment of groundwater using various methods (e.g. carbon absorption). Treatment may meet the RAOs for soil, groundwater, and landfill gas if effective treatments can be found for this application.

3.2.6 Disposal

Treated or untreated wastes can be disposed of either on or off site. Disposal options determine the ultimate location of treated or untreated media in an environmentally sound, publicly acceptable, and cost-effective manner. Disposal actions typically do not involve reduction of the toxicity or volume of contaminated media but may, in certain circumstances, reduce contaminant mobility due to associated containment. Disposal would meet the RAO for contaminated solid media.

3.2.7 Active Gas Control Actions

Gas extraction wells equipped with vacuum blowers with combustion technologies are an example of an active gas control technology. Active gas migration controls require an outside power source to control the migration of landfill gas. Redirecting gas flow by means of pressure gradients minimizes off-site gas migration and, therefore, meets the RAO for landfill gas.

3.2.8 Passive Gas Control Actions

Passive gas migration control actions do not require an outside power source to control landfill gas migration. Gas vents are an example of passive control technology. These actions provide a low resistance pathway for gas to escape to the surface, reducing the potential for off-site subsurface migration. There are no existing or planned structures near the landfill, making the potential for accumulation in a structure unlikely.

Some passive gas collection systems vent landfill gas to the atmosphere without any treatment before release. This may be appropriate if only a small quantity of gas is produced. The collected landfill gas may also be controlled and treated. Common methods to treat landfill gas include combustion technologies, such as flares, and noncombustion technologies and odor control. Passive gas control actions would meet the RAO by eliminating the migration pathway.

3.3 IDENTIFICATION AND EVALUATION OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

In this section, a range of remedial technology types and process options are identified and evaluated. Process options are specific for each technology type and each technology type may have several options. An example is a landfill cap as the technology type, with the variations for landfill caps as process options. The representative process option provides a basis for developing performance specifications during preliminary design; however, the specific process used to implement the remedial action at the site may not be selected until the remedial design phase. In some cases, more than one process option may be selected for a technology type if two or more processes are sufficiently different in their performance or implementability.

The process options are evaluated based on three criteria: effectiveness, implementability, and cost. These factors are described below:

Effectiveness

Effectiveness is the measure of (1) the potential of a process option to handle the estimated areas or volumes of media and meet RAOs and ARARs; (2) the potential impacts to human health and the environment during implementation; (3) how proved and reliable the process is with respect to the contaminants and conditions at the site; and (4) the ability to reduce, eliminate, or control current and potential risks.

Implementability

Implementability encompasses both the technical and the administrative feasibility of applying a remedial technology. Technical implementability eliminates those technologies that are clearly impractical at a site. Some technologies are in the demonstration stage, therefore, limited information may be available regarding technical and administrative feasibility. In some cases, treatability studies may be required before full-scale implementation. These aspects include the availability of equipment, time required to apply the technology, and the availability of construction materials.

Another aspect of implementability is the evaluation of transfers of contamination from one media to another and the need for additional treatment systems for secondary waste streams.

Cost

The estimated costs are presented as high, moderate, or low to provide relative costs of technologies rather than detailed estimates. These relative costs have been estimated based on information provided by vendors, published data, guidance documents, and engineering judgment.

3.3.1 Containment Area

This section presents the preliminary identification, development, and evaluation of technology types and associated process options for the Resource Conservation and Recovery Act (RCRA)/Facility Landfill and areas inside the Containment Barrier. Table 3-17 identifies technology types and process options and summarizes the evaluation of process options for landfill refuse inside the Containment Barrier.

3.3.1.1 Landfill Refuse and Contaminated Soil

3.3.1.1.1 Management and Institutional Controls

Management and institutional controls for landfill sites include land use and access restrictions. Land use and access restrictions reduce the potential for direct contact with refuse and leachate for human receptors by using restrictive covenants, fencing, and signs. These restrictions can also protect the integrity of other potential components of the remedial alternative, such as a landfill cap, and therefore reduce maintenance by controlling damage and erosion due to trespassing. Land use restriction notations for the Containment Area are discussed below.

Land Use Restrictions

Land use restrictions in deeds, use agreements, and updates to master plans can help to limit site use and development. These mechanisms will notify planning personnel that the land was once used for waste disposal and restrict future land use in order to protect the integrity of the waste containment system. The effectiveness of such actions depends on the United States Department of the Navy (DON) management of the property and is expected to yield positive results. Under the Environmental Services Cooperative Agreement WESTON is required to maintain and monitor the landfill during the post-closure operations and maintenance (O&M) phase.

Conditions in the area will be evaluated in the 5-year site review required under the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Land use restrictions for the Containment Area may include deed restrictions and notation in the master plan and any updated reuse plans to prevent future construction activities and agricultural,

commercial, or residential land use, as well as any groundwater extraction for agricultural or residential use.

Access Restrictions

Access restrictions consist primarily of fencing and signs. Fencing provides a barrier that limits access to the Containment Area. Signs posted along the perimeter of the site and along roads leading to the site make it clear to potential trespassers that there may be a health threat associated with the site. Phone numbers may be posted on signs for emergencies and if further information is needed.

Restricting access to the site is a low capital alternative that is effective in reducing the risk of human exposure to landfill refuse and contaminated soil. This action alone however, would not be effective in controlling the potential for surface migration of materials by wind or water, eliminating exposure to environmental receptors, and reducing the potential for erosion. Access restrictions will provide short-term protection to human health by restricting access during remediation.

Although land use restrictions and access restrictions alone would not meet the RAO for landfill refuse, they can be used in combination with other technologies during the remedial action to prevent human exposure and protect the potential landfill cap option. Therefore, land use notations and access restrictions during remediation will be retained for further evaluation in this FS. These actions are both readily implementable and relatively inexpensive.

3.3.1.1.2 Containment Actions

Containment actions isolate landfill refuse and contaminated soil, minimize disturbance of contaminated media, and limit off-site surface migration of contaminants. Containment actions are the most common and typically the most practical remedial actions used in addressing landfill sites. Containment is preferred for sites that present relatively low long-term threat or where treatment is impractical. As stated in 40 CFR 300.430(a)(1)(iii)(B), the EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.

Containment actions are effective in preventing adverse human and ecological exposure to landfill refuse. Surface controls and capping are two types of containment technologies.

Surface Controls

Surface controls channel and direct site runoff and prevent run-on from off-site surface water. These technologies are used in conjunction with landfill caps and slow the rate of cap erosion. Landfill caps may be susceptible to erosion that could expose and mobilize contaminated materials. Surface controls most commonly used at landfill sites are ditches, grading, and revegetation.

Grading reshapes topography to promote positive drainage and control surface water. Grading is also used to prevent the occurrence of ponds or puddles. A properly graded cap will channel surface water away from the landfill. Grading the surface of landfills helps to control erosion.

Designing proper slope lengths, gradients, berms, and swales are common techniques used to control and route surface water. They are typically combined with other technologies, such as the placement of a relatively impervious landfill cap and revegetation to minimize erosion, infiltration, and control surface water.

Revegetation is used to reduce erosion of the surface soil and promote evapotranspiration. Revegetation also tends to improve the aesthetics of the landfill. A revegetation plan includes selecting suitable plants for the area, soil preparation, seeding, planting, mulching, and maintenance.

A growth of dense vegetation helps minimize erosion because plants with a healthy root structure will hold the soil in place. Healthy top growth also helps to minimize erosion by buffering the physical effects of rainfall and wind on the soil. An established dense cover of surface vegetation can successfully hold surface soil loss to less than 2 tons per acre per year as calculated using the United States Department of Agriculture Universal Soil Loss Equation. Vegetation increases evapotranspiration and helps minimize rainwater percolation into the landfill. The cap must have sufficient thickness to accommodate the root systems of the selected and anticipated plant species, allow for long-term erosional losses, and provide water-holding capacity. Water holding

capacity sustains vegetation growth and minimizes infiltration. The vegetation should include perennial plants and grasses that are adapted to the local climate and soil conditions.

Surface controls are effective, readily implementable, require relatively low capital and O&M costs, and are combined with other response actions such as capping. These technologies will be considered further in this FS.

Capping

Caps, or cover systems, isolate landfill refuse and contaminated soil, prevent direct contact with wastes, and reduce water infiltration and subsequent leachate generation. Caps can also control emissions of landfill gases and odors, reduce erosion, and prevent rodent burrows from extending into the landfill refuse. Capping technologies evaluated in this FS are as follows:

- Native soil cap
- Multilayer cap including RCRA Subtitle C cap or RCRA equivalent cap (RCRA cap)
- Multilayer cap meeting California requirements but not the prescriptive RCRA Subtitle C requirements (e.g. RCRA Subtitle D)

Native soil caps are typically used when the primary objective is to control erosion and to prevent direct contact with landfill refuse (EPA, 1991) and/or when limiting infiltration is not a controlling factor. Infiltration is not a significant design consideration when the majority of refuse is below the water table, lowering the water table is impractical, and/or minimal groundwater contamination exists (EPA, 1991). A typical native soil cover is 18 to 36 inches thick. In arid regions, native soil caps can limit infiltration through evapotranspiration and increased field storage capacity. Federal and state landfill closure regulations include provisions for the use of native soil covers as acceptable engineered landfill caps, when appropriate to the landfill and site conditions under consideration.

Multilayer cap technologies are appropriate when leaching of hazardous compounds to groundwater is expected to contribute to unacceptable human health and environmental risks (EPA, 1991). Multilayer caps are typically required by state and federal regulations for operating permitted landfills and are typically installed at closure. Multilayer caps can be appropriate for

the Comprehensive Environmental Response, Comprehension, and Liability Act (CERCLA) landfills when minimizing infiltration, leachate generation, and leachate migration are critical.

A RCRA Subtitle C (hazardous waste landfill) cap works by maintaining a multi-layer, low-permeability cover over the waste to stabilize surface soil and reduce surface water infiltration. Performance standards for caps typically require minimum liquid migration through the wastes, low cover maintenance requirements, efficient site drainage, high resistance to damage by settling or subsidence, and a permeability lower than or equal to the underlying liner system or natural soils. RCRA Subtitle C equivalent hazardous waste cap designs typically include, from the top down, a 24-inch thick layer of cover soil, a drainage layer, a geosynthetic membrane layer, and a 24-inch thick layer of low permeability compacted clay or equivalent geosynthetic clay liner (GCL), a gas collection layer (if applicable), and a 24-inch foundation layer.

The multilayer cap design standards in California Code of Regulations (CCR), Title 27, Division 2, Section 21140, for closure of a non-hazardous solid waste landfill include, at a minimum from the top down, a 12-inch erosion-resistant soil layer, a 12-inch low hydraulic conductivity clay layer (or an equivalent GCL), and a 24-inch foundation layer. RCRA Subtitle D solid waste landfill cover requirements consist of, at a minimum, from the top down, a 6-inch topsoil layer and an 18-inch low permeability clay layer (or equivalent GCL). The regulations allow for engineered alternatives to the prescribed standard.

Each of the described cover systems, RCRA Subtitle C equivalent cover, CCR Title 27, Division 2, Section 21140 cover, or a RCRA Subtitle D Cover can, if properly designed, satisfy post-closure requirements for interim-status landfills specified in CCR Title 22, Division 4.5, Sections 66265.111 and 66265.310. Since a portion of the containment Area includes RCRA regulated units, the RCRA Subtitle C requirements would be an ARAR for these units.

Groundwater data from the Containment Area indicate that there is a potential risk to ecological receptors from groundwater migration off site. An Interim Remedial Action Plan was completed in September 2004 (WESTON, 2004b) to address the groundwater movement by constructing a Containment Barrier (a slurry wall and a groundwater extraction trench inside the slurry wall). Infiltration is a main consideration in reducing the amount of contamination reaching

groundwater and ensuring that the Containment Barrier operates effectively. Therefore, a native soil cap would not meet the RAOs and will not be carried forward for further discussion in this FS for the Containment Area.

The multilayer cap designs complying with CCR, Title 27, Division 2, Section 21140 for non-RCRA areas or RCRA Subtitle C or equivalent for RCRA areas and which also comply with CCR, Title 22 interim status facility landfill post-closure requirements, are effective, implementable, require relatively moderate capital and O&M costs, and may be combined with other response actions. These technologies will be considered further in this FS.

3.3.1.1.3 Removal and Disposal

Removal and disposal involves excavating refuse and contaminated media and disposing of the material off site. If landfill contamination is distributed in a heterogeneous manner, it is unlikely that removal of all affected materials can be ensured without removal of the entire landfill. Removal and disposal of material in another landfill essentially moves contamination from one area to another.

The effectiveness of the removal option is questionable at best. This option entails excavating, handling, and moving along public roads over 50,000 truckloads of waste. This option poses a potential elevated risk to excavation and site workers from uncovered contaminated materials and any MEC and Mare Island residents due to the volume of heavy truck traffic. The overall removal option is not proven successful and in the detailed analysis EPA performed on landfill FSs, all the studies screened out removal as an option (EPA, 1993). This option does not reduce or eliminate risks but will temporarily increase risks during implementation.

The implementability of this option is also questionable. The equipment needed to move the amount of material in a reasonable time frame, capacity in other landfills, and the amount of clean fill required for re-grading after the removal may be difficult to obtain.

The cost of removal and disposal is also significantly higher than any other option. Removal is not normally an option considered for large landfills where a “presumptive remedy” based on EPA’s experience normally allows for the screening out of overall removal at an early stage.

This option is being retained for further consideration at the request of the regulators. More information regarding landfills and presumptive remedies is presented in Section 3.3.1.4.

3.3.1.2 Groundwater and Leachate

This section presents the preliminary identification, development, and evaluation of technology types and associated process options for groundwater and leachate inside the Containment Barrier. Capping controls, eliminates, or reduces infiltration into the landfill and potentially to groundwater. Capping options have already been described. Options for reducing horizontal migration of contaminated groundwater and treatment are discussed below.

Physical Barriers

Physical barriers are used when it is desirable to contain contaminants in place, rather than remove and/or treat the contaminated media. These passive techniques focus on limiting hydrologic pathways for contaminant migration. Several options exist for vertical barriers including GundWall Panels, high-density polyethylene (HDPE) Polywall Barriers, and Soil-Bentonite Slurry Walls. Each is described briefly below.

GundWall Panels consist of HDPE panels with interlocks on each side, which are installed vertically to create an impermeable barrier. The panels are 6 to 8 feet wide and fabricated to the desired length and thickness. These panels can be installed using a steel plate and crane-mounted vibratory hammer, which vibrates the panels into the ground. An anchor wedge, seamed to the leading edge of each panel, facilitates installation. A hydrophilic sealant material is fed into the panel interlocks, which swells in contact with water, providing a nearly water-tight seal between panels.

Polywall is a non-permeable HDPE barrier with a hydraulic conductivity of $1x10^{-13}$ centimeters per second (cm/s). The HDPE material, like that used in the GundWall, is very resistant to chemical degradation. A 22-foot wide roll of the HDPE barrier is placed vertically into a trench and the barrier is unrolled as the trench proceeds. Installation of the Polywall requires a narrow trench for installation, and the native soil cuttings are used for backfill. The depth of the barrier is limited by the width of the manufactured HDPE rolls, which is typically 22 feet. The length of

each roll is several hundred feet long, and requires that a new roll be heat-welded to the previous roll. Both the GundWall and Polywall Barriers cannot be installed in areas containing debris which would interfere with the installation. Due to the wide-spread disposal of construction debris and similar materials throughout IA-H1, these barriers would not be readily implementable.

Slurry walls are nonstructural barriers constructed underground to contain contaminated groundwater. The slurry wall creates a vertical barrier to restrict horizontal migration of contaminated groundwater beyond the limits of the landfill. There are different materials and combinations of materials that can be used to construct slurry walls, including soil-bentonite, cement-bentonite, and plastic concrete. The application of slurry walls involves excavation to the desired depth and eventual displacement of the slurry by a permanent backfill, which forms the hydraulic barrier. Slurry walls have been used successfully for decades. One advantage of slurry walls is that the soil mixture can be designed to have low enough shear strength, such that the wall will be self-healing. This is especially useful in areas where earthquakes are common.

A slurry wall, as with any vertical barrier employed at IA-H1, would be keyed a minimum of 5 feet into the confining Young Bay Mud layer throughout the entire RCRA/Facility Landfill perimeter. The bentonite slurry creates a filter cake on the sides of the trench as the slurry flows laterally into the soil. This filter cake consists of a layer of bentonite with low permeability. The slurry also hydraulically shores the trench to prevent collapse and produces a filter cake along the sides to reduce groundwater flow. A completed bentonite slurry wall will typically result in a permeability of 10^{-7} cm/s, which represents a water movement of only 0.1 foot per year through the slurry wall itself.

Physical barriers can be effective in meeting the RAOs. The slurry wall is proven implementable and appropriate for earthquake-prone areas. The cost is moderate and it has a proven track record of effectiveness. The slurry wall has been retained for further evaluation in this FS.

Groundwater/Leachate Extraction

Groundwater extraction is beneficial to reduce mounding of water inside the vertical barrier and produce an inward hydraulic gradient to further reduce the potential for lateral migration. Among

the few methods that exist for extracting groundwater from the subsurface are point well extraction and trench collection. Both are explored below.

An effective point well extraction system is designed so that wells are spaced to ensure overlapping zones of influence. This ensures groundwater will flow toward the extraction wells rather than build up along the inside of the vertical barrier. A zone of influence can be predicted using either soil data or implementing a pilot study. Groundwater wells are installed and screened in the saturated zone. Each well flows into a pipe network and eventually off site. Available soil data from IA-H1 suggest a heterogeneous subsurface, with high clay content and low permeability. Because of the high clay content and low permeability, it is likely that wells would have to be spaced tightly in the region just inside the containment wall. Because of the subsurface heterogeneity, it would still be possible for an unknown seam or other conduit to direct water toward the containment wall, bypassing an extraction well, even if the wells were properly spaced.

A trench collection system provides an alternate way to extract groundwater from the contained area. A trench wrapped with a permeable geotextile fabric and filled with drainage material such as washed gravel, is constructed to intercept groundwater along an entire plane. The trench is sloped such that groundwater flows toward a sump, where submersible or pneumatic pumps lift the water into a piping network. The focus of groundwater extraction is to prevent buildup near the containment wall. The biggest advantage of the trench collection design is that it is virtually impossible for groundwater to flow from the inside of the containment system toward the perimeter wall without being captured in the trench. This option is retained for further analysis in this FS.

Treatment

Extracted groundwater is treated solely for the purpose of meeting discharge or disposal criteria. The water may or may not require treatment before discharging to local publicly owned treatment works (POTW). The amount of water extracted from the Containment Area is anticipated to decline over time as remedies to reduce infiltration are implemented and the mounded water in the refuse is reduced through collection. Treatment will depend on the

chemical contaminants found in the extracted water. Preliminary analyses of potential contaminants in water in and under the landfill indicate that petroleum contamination is the most likely component to require treatment. In order to achieve the acceptance requirements of the Vallejo Sanitation and Flood Control District (VSFCD), interim field-scale pilot testing was performed. The results indicated that the water meets the acceptance criteria of the VSFCD. Collection and treatment are effective, implementable, and have a range of low to high cost depending on the level of treatment required. Therefore, the treatment option will be retained for further analysis in this FS.

3.3.1.3 Landfill Gas

Developing appropriate remedial alternatives involves identifying the specific technology types and process options associated with the general response actions discussed in Section 3.2. This section presents the preliminary identification, development, and evaluation of technology types and associated process options for landfill gas.

Decomposing organic materials in landfills generate gases, which can migrate vertically and horizontally. Landfill gases produced during degradation include carbon dioxide and methane; VOCs are also released during the degradation process. Landfill gas control should be considered when structures are nearby, when emissions pose an unacceptable health risk, when odors are a problem, or when low permeability caps are constructed. Low permeability caps placed over landfills can cause gas pressure to build up. The increase in gas pressure can damage the cap and increase horizontal gas migration. Therefore, landfill gas process options are considered further in this FS.

3.3.1.3.1 Monitoring

Gas monitoring is conducted, when required, in accordance with applicable regulations to assess off-site migration of landfill gases. CCR Title 27 regulations require that gas monitoring wells be placed around a landfill perimeter, spaced no more than 1,000 feet apart. The exact placement depends on surrounding geography and lithology. Gas monitoring actions are readily implementable and have low costs. It is possible that continued gas monitoring over a long

period of time may not be required if it can be shown that all the criteria for an exemption to gas monitoring under CCR Title 27, Division 2, Section 20918, can be met. This determination would likely be made following real-time methane gas sampling. Monitoring is also useful in determining if treatment will be necessary. Monitoring will be retained for further evaluation in this FS.

3.3.1.3.2 Passive Gas Actions

Passive landfill gas control systems alter subsurface gas flow pathways without using powered mechanical components. Generally, they direct subsurface flow to points of release by providing a low resistance pathway. Passive systems are not used to recover landfill gas, but to control the migration of gases by venting to the atmosphere. Typical passive low resistance systems include pipe vents, trench vents, and gas venting layers in the cap. Low permeability barriers including clay-lined or synthetic-lined perimeter trenches or walls can also redirect flow paths to outside areas. Gas production is occurring within the Containment Area; however, landfill gas monitoring indicates low levels of production. Therefore, passive gas controls will be retained for detailed analyses in this FS.

3.3.1.3.3 Active Gas Control Actions

Active systems use a power source and mechanical means to alter pressure gradients and redirect subsurface gas flow (EPA, 1991). Major system components generally include gas extraction wells, gas collection headers, vacuum blowers or compressors, and gas treatment or recovery systems. Thermal (ground flares, catalytic incineration), chemical (vapor phase ultraviolet oxidation), and physical treatment (granular activated carbon adsorption) systems can be used to treat landfill gas. Also, landfill gas recovery and sale (for use as a source of energy) is possible with active systems.

Active landfill gas control and treatment systems are typically implemented at sites where severe odor problems exist, if human inhalation risks are unacceptable, when ARARs require treatment of emissions, when there is high potential for gas to migrate into nearby structures, or when high volumes of gas generation make gas recovery economically desired. No odor problems have been noted in the RCRA/Facility Landfill area and there are no nearby buildings. Low volumes

of gas are likely being generated due to the size, types of waste, and age of the RCRA/Facility Landfill. Therefore, active gas controls will not be retained for detailed analyses in this FS.

3.3.1.4 Remedial Technologies and Evaluation of Presumptive Remedies

The EPA develops presumptive remedies by studying the results of technology selections and performance for common categories of sites. The EPA develops "presumptive remedies" that eliminate duplicate analyses for sites with common characteristics. The objective of the presumptive remedy initiative is to use past experience from CERCLA sites to streamline site investigation and speed up selection of cleanup actions. Over time, presumptive remedies are expected to ensure consistency in remedy selection and reduce the cost and time required to clean up similar sites. The EPA studied the remedy selection of a random sample of CERCLA municipal landfills (30 of 149 sites with final remedies selected) and found that containment was chosen as a component of the selected remedy at all 30 of the sites analyzed. No other technologies were as consistently selected. Therefore, containment was identified as the presumptive remedy (EPA, 1993).

Section 300.430(a)(1)(iii)(B) of the NCP discusses the expectation that engineering controls, such as containment, will be used for waste that poses a relatively low long-term threat or where treatment is impracticable. The size (generally over 100,000 cubic yards) and type of materials (heterogeneous mixture of municipal waste, frequently co-disposed with industrial waste, hazardous waste, or both, and present in large volumes) of the IA-H1 RCRA/Facility Landfill match the criteria for sites using the landfill presumptive remedy.

In addition to directives on municipal landfills, the EPA has developed guidance specific to military landfills (EPA, 1996). EPA guidance states that the municipal landfill presumptive remedy should be applied to all appropriate military landfills. Key factors determining the applicability of the presumptive remedy at military landfills include the following:

- Size of the landfill
- Volume and type of landfill contents
- Future land use of the area
- The presence, proportion, and distribution of military-specific wastes

The available data as discussed in the Final RI for IA-H1 (WESTON, 2005a) show that the containment presumptive remedy is appropriate for the IA-H1 RCRA/Facility Landfill.

The presumptive remedy for CERCLA municipal landfill sites recommends (1) containment of the landfill mass and (2) collection and/or treatment of landfill gas. In addition, if necessary, measures to control landfill leachate, affected groundwater at the perimeter of the landfill, and/or upgradient groundwater that is causing saturation of the landfill mass, may be implemented as part of the presumptive remedy (EPA, 1993). The presumptive remedy and an additional removal option will be evaluated further in this FS.

3.3.2 Upland and Non-Tidal Wetland Areas outside the Containment Barrier

This section presents the preliminary identification, development, and evaluation of technology types and associated process options for the Upland and Non-Tidal Wetland Areas outside the Containment Barrier. Tables 3-18 and 3-19 identify technology types and process options associated with each GRA for soil and sediment in the Upland Areas outside the Containment Barrier; Tables 3-20 and 3-21 identify technology types and process options associated with each GRA for soil and sediment in the Non-Tidal Wetland Areas outside the Containment Barrier. These technology types and process options represent the range of remedial technologies potentially applicable to contaminated media.

The remedial technology types and process options for soil and sediments in the Upland and Non-Tidal Wetland Areas were identified based on the following reference sources:

- Remediation Technologies Screening Matrix and Reference Guide, Second Edition (United States Department of Defense [DOD], 1994)
- EPA Vendor Information System for Innovative Treatment Technologies
- Federal Remediation Technologies Roundtable
- Superfund Innovative Technology Evaluation Program
- National Technical Information Service Bibliographic Database
- Literature search on various technical journals and conference proceedings

The preliminary remedial technologies were screened for technical implementability based on site and waste characteristics. The results of this screening are outlined in Tables 3-17 through 3-20.

3.3.2.1.1 Management and Institutional Controls

General descriptions of management techniques and institutional controls are provided in Section 3.3.1.1. Specific options for the Upland and Non-Tidal Wetland Areas are described below.

Management and institutional controls for the soil and sediment in the Upland and Non-Tidal Wetland Areas include land and groundwater use restrictions and access restrictions to reduce the potential for direct contact with soil, sediment, and groundwater by human receptors. This may be achieved by using restrictive covenants, fencing, and signs and by providing an alternate water supply. These restrictions will also protect the integrity of other potential components of the remedial alternative and reduce maintenance by controlling damage and erosion due to trespassing.

Land use restrictions for the soil and sediment in the Upland and Non-Tidal Wetland Areas may include deed restrictions and notation in the master plan and any updated reuse plans to prevent future construction activities and agricultural, commercial, or residential land use, as well as any groundwater extraction. The notations will notify planning personnel that the soil, sediment, and groundwater were once contaminated and will restrict future land use in order to protect the integrity of the selected remedial alternative. The effectiveness of such actions depends upon the DON's management of the property and is expected to yield positive results. Conditions in the area will be evaluated in the 5-year site review required under SARA.

Access restrictions consist primarily of fencing and signs. Fencing provides a barrier that limits access to the site. Signs posted along the perimeter of the site and along roads leading to the site make it clear to potential trespassers that there may be a health threat associated with the site. Phone numbers may be posted on signs for emergencies and if further information is needed.

Access restrictions are low capital alternatives that are effective in reducing the risk of human exposure to soil and sediment. These actions alone however, would not be effective in

controlling the potential for surface migration of materials by wind or water, eliminating exposure to environmental receptors, and reducing the potential for erosion. Access restrictions will provide short-term protection to human health by restricting access during the construction phase of remediation.

Although land and groundwater use restrictions and access restrictions alone would not meet the RAOs, they can be used in combination with other technologies during the remedial action to prevent human exposure and protect the selected remedial option. Therefore, land and groundwater use notations and access restrictions during remediation will be retained for further evaluation in this FS. These actions are readily implementable and relatively inexpensive.

Sediment monitoring is a management tool that involves monitoring changes in contaminant concentrations in sediment. It is effective in discovering any changes in contaminant concentration in sediment in the Non-Tidal Wetland Areas, is readily implementable, and relatively inexpensive. Therefore, sediment monitoring will be retained for further evaluation in this FS.

3.3.2.1.2 Containment Actions

Containment actions isolate soil and sediment and limit off-site surface migration of contaminants. Containment is effective in preventing adverse human and ecological exposure to site contaminants and is generally preferred for sites that present relatively low long-term threat or where treatment is impractical.

Section 3.3.1 contains a discussion of various cap designs. A compacted, low-permeability soil cap would act as a barrier to prevent ingestion, direct contact, and inhalation of contaminants in soil to human and ecological receptors. A soil cap would also reduce the mobility of contaminants by minimizing their vertical migration to groundwater. Capping, however, would not be effective for localized “hot spots”. A soil cover will be retained for further evaluation in this FS.

3.3.2.1.3 Collection Actions

Collection actions for the soil and sediment in the Upland and Non-Tidal Wetland Areas include soil and sediment excavation. Excavation is an effective and implementable option for handling contaminated soil and sediment in limited "hot spot" areas and prevents ingestion, direct contact, and inhalation of contaminants in soil and sediment to human and ecological receptors.

Excavated soil may be used in combination with treatment, such as stabilization. The excavated soil may require dewatering and this associated water may require management. Collection technologies must be teamed with a disposal technology and may also require treatment prior to disposal.

3.3.2.1.4 Disposal Actions

Disposal actions involve the disposal of excavated material on site. Treated soil would be placed back into excavated "hot spot" areas or untreated soil would be combined with other disposal materials within the IA-H1 RCRA/Facility Landfill Area. These disposal actions, in conjunction with collection actions, can be readily implemented at a relatively low cost.

Off-site disposal options essentially only transfer contaminants from one area to another, i.e., an off-site disposal facility. Soil and sediment would have to meet land disposal restrictions prior to disposal, if necessary. Although this action is implementable, it requires handling and transportation of contaminated soil and much higher costs than on-site disposal.

3.3.3 Summary of Technology Screening for IA-H1

The applicable technologies for addressing the Containment Area that will be considered further in this FS include the following:

- Deed and access restrictions to prevent or limit site access, use, and development
- Soil cover containment to minimize exposure to landfill refuse by preventing direct contact with surface soils and reducing erosion, migration, and infiltration
- Removal and disposal of landfill refuse and contaminated soil to eliminate exposure (by request of the regulators)

- Groundwater containment with or without treatment to prevent the migration of contaminated groundwater
- Passive landfill gas collection and venting, and landfill gas monitoring

The process options and technology types that were selected for further evaluation in the FS for the Upland and Non-Tidal Wetland Areas outside the Containment Barrier include the following:

- Institutional controls and land use and access restrictions to prevent or limit site access, use, and development; groundwater use restrictions
- Containment to minimize exposure to site contaminants by preventing direct contact with surface soils and reducing erosion, migration, and infiltration
- Collection to eliminate exposure to site contaminants by preventing direct contact with surface soils and reducing erosion, migration, and infiltration
- On-site consolidation to transfer contaminated materials to the Containment Area, where capping under the presumptive remedy minimizes exposure by preventing direct contact with surface soils, and reducing erosion, migration, and infiltration. Materials excluded from consolidation into the Containment Area will include, free liquids (drums, etc.), excessively leachable materials or those containing high concentrations of volatile organic compounds.

4. DEVELOPMENT OF REMEDIAL ALTERNATIVES

This step in the Feasibility Study (FS) process develops the remaining process options from the technology screening process into remedial alternatives. Alternatives are typically assembled, refined, and screened based on effectiveness, implementability and cost. The screening may lead to a reduction in the numbers of alternatives selected to progress to the next step of detailed analysis. However, when circumstances limit the number of available options and the number of alternatives developed, it is not necessary to screen alternatives before the detailed analysis (United States Environmental Protection Agency [EPA], 1988).

The following sections outline the alternatives for the Containment Area and the Upland and Non-Tidal Wetland Areas outside the Containment Barrier. These alternatives will move on to detailed analysis in Section 5.

4.1 CONTAINMENT AREA ALTERNATIVES

Three remedial alternatives were assembled based on process options remaining from the technology screening process, site-specific conditions, EPA guidance, and regulator requests. These alternatives are as follows:

- Alternative 1–No Action
- Alternative 2A–Variable Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring
- Alternative 2B–Resource Conservation and Recovery Act (RCRA) Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring
- Alternative 3–Removal and Disposal

Because the alternatives developed for the Containment Area are based on EPA presumptive remedy guidance for streamlining the FS process (1993, 1996) and by regulator requests, the alternatives will not undergo further screening and will be analyzed in detail in Section 5. The alternatives for the Containment Area are described below.

4.1.1 Alternative 1—No Action

Under the "No Action" alternative, no remedial actions will be implemented. Actions required for interim status of the RCRA regulated units within Investigation Area H1 (IA-H1) would be continued; however, no other actions would be taken. The "No Action" alternative is reviewed to provide a baseline against which other alternatives can be compared.

4.1.2 Alternative 2A—Variable Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring

Alternative 2A consists of land use and access restrictions, a variable multilayer cap (with surface drainage and erosion controls); a groundwater Containment Barrier; an extraction trench for groundwater containment; and gas venting and monitoring. A multilayer cap, described in Sections 4.1.2.1 and 4.1.2.2, will be implemented under this alternative to isolate landfill refuse, eliminate direct contact with surface soil, reduce erosion, reduce surface soil contaminant migration, and limit surface water infiltration. The Final Remedial Investigation (RI) (Weston Solutions, Inc. [WESTON], 2005a) did not attempt to fully characterize the RCRA/Facility Landfill content because of its heterogeneous nature and because the presumptive remedy for landfills, i.e., containment, would be the most likely remedy. A RCRA Subtitle C multilayer cap will cover the RCRA interim status hazardous waste landfill, the Industrial Wastewater Treatment Plant (IWTP), and the Facility Landfill inside the Containment Area (for a total of approximately 32 acres). The footprint of the RCRA and Facility Landfill includes the bulk of waste disposed of within the Containment Area, as evidenced by the higher topography in this portion of the Containment Area. A RCRA Subtitle D multilayer cap (non-RCRA hazardous waste cap) will cover the remaining areas within the Containment Barrier (approximately 40 acres). Figure 4-1 shows the respective areas. A fence will be constructed around the Containment Area to exclude public access.

Both multilayer caps, as described in Sections 4.1.2.1 and 4.1.2.2, will satisfy performance requirements contained in California Code of Regulations (CCR), Title 27 (27 CCR), Chapter 3, Subchapter 5, Article 2, Section 21140 and CCR, Title 22,66526. The portion of the cap over the RCRA regulated units and Facility Landfill will also comply with Title 40 Code of Federal

Regulations (CFR) RCRA Subtitle C regulations. Public access will not be allowed for the Containment Area with this proposed remedy.

4.1.2.1 RCRA Equivalent Cap

A RCRA Subtitle C cap works by maintaining a multilayer, low-permeability cover over the waste to stabilize surface soil and reduce surface water infiltration, which in turn limits leachate and landfill gas generation. Performance standards for caps under CCR Title 22 and Title 27 and Title 40 CFR require minimum liquid migration through the wastes, low maintenance cover requirements, efficient site drainage, high resistance to damage by settling or subsidence, and a permeability lower than or equal to the underlying liner system or natural soils. The Young Bay Mud underlying the IA-H1 area has a permeability of $2x10^{-7}$ centimeters per second (cm/s) as reported in the Final RI (WESTON, 2005a).

The standard RCRA Subtitle C cover design (EPA, 1991) includes the following components (from top to bottom):

- 6 inches of vegetative cover soil
- 18 inches of cover soil
- filter layer
- 12-inch-thick drainage layer
- 20-mil geomembrane
- 24 inches of low-permeability compacted clay layer (CCL)

A RCRA equivalent cover is allowed to be substituted for the standard RCRA cap design if it meets or exceeds the performance of the original design. A RCRA equivalent cap is proposed for this site. WESTON submitted an equivalent cover design document to the California Department of Toxic Substance Control (DTSC) in August 2005 (WESTON, 2005d). The equivalent cover designs in the document were evaluated for their performance in regard to minimizing percolation and providing a low permeability layer, withstanding potential earthquake forces, and possessing long-term durability.

The proposed equivalent cover design document incorporates geosynthetic materials that have been developed and refined over the past 10 to 15 years. The materials that will be incorporated in the equivalent cover have been developed and tested by manufacturers, studied and evaluated by academicians, and reviewed and approved by regulators across the United States. Use of these geosynthetic materials will provide greater protection of the environment and reduce construction time and cost.

The proposed equivalent cover design includes a Geosynthetic Clay Liner (GCL) to replace the original RCRA standard CCL. GCLs offer many advantages over CCLs. These include: better performance under wetting and drying cycles, greater tolerance for total and differential settlement, easier placement, more rapid installation, reduction in air pollution, less complex oversight required, less dependence on weather during installation, and are less expensive to install. GCL-based cover systems have been successfully installed throughout the United States and can likewise be successfully installed at Mare Island IA-H1 to provide long-term protection of the environment (WESTON, 2005d).

The proposed design for the RCRA regulated units cap is shown in Figure 4-2 and consists of the following components (from top to bottom):

- 6 inches of vegetative cover soil
- 18 inches of cover soil
- single-sided geocomposite drainage layer
- 60-mil smooth high-density polyethylene (HDPE) geomembrane
- geotextile-encased GCL
- doublesided, nonwoven geotextile (gas venting layer)
- 24 inches of foundation material

4.1.2.2 Non-RCRA Cap

The non-RCRA multilayer cap (non-RCRA hazardous waste cap) is specifically designed to reduce infiltration and meets the minimum design requirements of 27 CCR, Chapter 3, Subchapter 5, Article 2, Section 21090 performance standards and minimum design requirements for a final landfill cover system. The sequence of layers in a typical multilayer cap

consists of, from the surface down, an erosion-resistant layer, a low-hydraulic conductivity layer, and a foundation layer.

The erosion-resistant layer, usually consisting of soil, supports vegetation and is typically at least 12 inches thick (27 CCR, Section 21090).

The low-hydraulic conductivity layer, typically consisting of compacted clay, is at least 12 inches thick (27 CCR, Section 21090) and functions to reduce infiltration as well as to control upward movement of landfill gases. The layer must meet minimum acceptable permeability requirements of $1x10^{-6}$ cm/s or be equal to the hydraulic conductivity of the underlying natural geologic material, whichever is less.

The foundation layer consists of a minimum 24-inch layer of compacted soil or waste materials, if suitable, to support the low-hydraulic and erosion-resistant layers (27 CCR, Section 21090).

The proposed design for the non-RCRA hazardous waste cap within the Containment Area is shown in Figure 4-3 and consists of the following components (from top to bottom):

- 6 inches of vegetative cover soil
- 18 inches of cover soil
- single-sided geocomposite drainage layer
- 60-mil HDPE geomembrane
- doublesided, nonwoven geotextile at high points (gas venting layer)
- 24 inches of foundation material

The non-RCRA cap will cover Wetland X and other small wetland areas in the Containment Area. These wetlands consist of 2.0 acres of pickleweed, 0.5 acres of seasonally ponded water, and 4.7 acres of low-value, disturbed seasonal wetlands for a total wetland area of 7.2 acres. An area of 6.7 acres of higher value pickleweed marsh and 1.5 acres of seasonal ponded wetlands (total of 8.2 acres) will be created in the Upland Areas of IA-H1 to offset the wetland impacts within the Containment Area. The created wetlands will triple the amount of salt marsh harvest mouse habitat compared with impacts, and increase the open water habitat for migratory birds. The proposed upland wetland creation will also connect existing isolated wetlands. The proposed wetland creation areas are currently uplands located mostly in the Demolition Debris and

Sanitary Sewage Treatment Plant Subareas of IA-H1. The excavation of soil containing elevated levels of contaminants (hot spots) and non-contaminated overburden soil down to the target wetland creation elevations will remove most of the contamination present in these areas. Sampling and analysis will be performed to ensure that the created wetland near-surface soil meets the risk-based criteria. Residual risk will be managed by institutional controls (land use restrictions and an operation and maintenance plan) to ensure future site activities do not destroy the created wetlands or create an exposure pathway for potential ecological or human receptors to contaminated soils at depths greater than the target exposure depths.

The overall goal of wetland mitigation is to replace lost wetland functions and values, as well as to create functional habitat for a variety of wildlife species, including the salt marsh harvest mouse. The development of the new wetlands will take place concurrently with wetland impact activities. Monitoring to ensure the created wetland is developing appropriately is included in the wetland mitigation plan (LSA Associates, Inc. [LSA], 2005b). Once established, the wetland will provide ongoing benefits. Appropriate protective measures will be implemented to minimize impacts on endangered species during construction of the cap in the Containment Area. These include appropriate trapping methods and passive relocation of salt marsh harvest mice. These provisions will be included in the final Biological Opinion, issued by the United States Fish and Wildlife Service. Vegetation will be cut or removed immediately after the final trapping interval to ensure the salt marsh harvest mice do not return to the area. The created wetlands will provide long-term equal or better value wetlands to the area.

4.1.2.3 Institutional Controls

Land use and access restrictions will be implemented as part of Alternative 2A to protect human health and as required by regulation. Land use restrictions would be placed on the site as deed restrictions, such as prohibiting residences, schools, day care centers, or hospitals; prohibiting cap, wetland habitat, or soil disturbance without United States Department of the Navy (DON) and California Environmental Protection Agency approval; performance of quarterly visual surveys; and implementation of an education and awareness program. Restrictions will also be put in place to preclude any groundwater extraction for agricultural or residential use.

Alternative 2A includes a 6-foot chain link fence with 3 strands of barbed wire around the entire Containment Area to restrict public access and protect the cap.

A plan for initiating and implementing trapping or other appropriate controls for burrowing animals, should the need occur in the future to protect the cap from damage, will be included in the design document.

4.1.2.4 Groundwater Containment

The Interim Remedial Action, completed in September 2004, includes a Containment Barrier, consisting of an approximately 7,300 linear foot low-permeability soil bentonite slurry wall that surrounds the Containment Area. The depth of the slurry wall ranges from 15 to 25 feet below ground surface (bgs) and extends 5 feet into a thick layer of natural clay.

Groundwater is collected and pumped out of the Containment Area. This is accomplished by use of two groundwater extraction trench systems, each equipped with a series of sumps and pneumatic pumps, and a forcemain, which transports the leachate to a collection system. The groundwater extraction trench is located approximately 20 feet from the inside of the Containment Barrier to provide optimal control of the groundwater mounding behind the Containment Barrier, while maintaining its structural integrity. The west trench is approximately 4,300 feet long and contains nine collection sumps. The east trench is 3,000 feet long and contains six collection sumps. Sumps are not more than 500 feet apart. They are connected with perforated high-density polyethylene (HDPE) pipe, sloped at a minimum of 1 percent towards the sumps. The HDPE pipe lies on a bed of 1 foot of washed gravel and is covered by washed gravel up to the historical high groundwater level. The washed gravel is then covered by native cuttings and ultimately will lie under a landfill cap. The collected groundwater leachate is sampled and analyzed to verify compliance with the discharge requirements of the Vallejo Sanitary and Flood Control District (VSFCD) sanitary sewer system, where it undergoes further treatment.

It is anticipated that the groundwater mound in the Containment Area could be reduced to equilibrium levels in 2 to 5 years. Groundwater levels in wells outside the Containment Area and piezometers inside the Containment Barrier will be monitored for groundwater levels to verify

that levels outside the Containment Barrier are higher than the levels along the extraction trench, to verify an inward hydraulic gradient. Extraction of groundwater will continue as necessary to maintain this inward gradient. Groundwater monitoring will also be performed in accordance with the post-closure sampling approach as described in the following section.

4.1.2.5 Groundwater Monitoring

A groundwater monitoring program is in place and will be revised upon application of the final cap and closure of the RCRA Landfill. The RCRA unit of the landfill is currently under interim status and subject to CCR, Title 22, Article 6 requirements. The monitoring plan is designed to meet RCRA Interim Status Facility and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements. The plan includes a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples that represent background water quality and the quality of groundwater passing the point of compliance. Upon completion of the cap and closure of the RCRA Landfill, a post-closure sampling plan will be implemented. The post-closure sampling plan will be designed to evaluate groundwater quality and to determine if the remedy is working adequately.

4.1.2.6 Gas Monitoring

A passive gas collection and venting system will be included in the RCRA and non-RCRA portions of the Containment Area cap. Gas concentrations will be monitored periodically, and a corrective action program will be implemented should action levels be exceeded. Based on soil gas data collected during the investigation phase, a limited volume of methane gas is currently being generated. Low concentrations of non-methane organic volatile compounds were detected outside the RCRA/Facility Landfill within the Containment Area based on limited soil gas characterization data. These results will be verified after implementation of the remedy.

4.1.3 Alternative 2B—RCRA Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring

Alternative 2B consists of land use and access restrictions; a RCRA Subtitle C equivalent multilayer cap (with surface drainage and erosion controls) over the entire Containment Area,

with gas venting; a Containment Barrier; an extraction trench for groundwater containment; and periodic gas monitoring. A RCRA multilayer cap will be implemented under this alternative to isolate landfill refuse, eliminate direct contact of surface soil, reduce erosion, reduce surface soil contaminant migration, and limit surface water infiltration. This alternative is identical to Alternative 2A, except that it extends the RCRA Subtitle C equivalent cap (described in Section 4.1.2.1) over the entire Containment Area. This alternative also includes a 6-foot chain-link exclusionary fence surrounding the entire Containment Area, and excludes any recreational (trails) use of the entire Containment Area as shown in Figure 4-4.

4.1.4 Alternative 3—Removal and Disposal

Alternative 3 consists of complete removal of the RCRA/Facility Landfill and contaminated areas within the Containment Barrier and disposal in appropriate hazardous waste or non-hazardous waste landfills. The major components of this alternative include the following:

- Mechanical excavation of contaminated soil, replacement with backfill to a sufficient grade using clean fill, and surface replacement
- Off-site disposal of contaminated soil and landfill refuse
- Engineering control measures to prevent airborne dust emissions from the site and to control surface erosion
- Safety procedures for identifying and handling potential MEC and radiological material

Due to the potential for MEC and radiological items to be inadvertently transported off-site with contaminated soil and debris, appropriate safeguards (e.g. mechanically screening soil and limiting excavation "lifts" to 1 foot to allow pre-excavation radiological surveys) would likely be required. This alternative would also require extensive odor and dust suppression, and a traffic control plan to manage up to 100 trucks per day during the construction season for a period of 2 to 3 years, to transport waste off-site.

4.2 UPLAND AREAS OUTSIDE THE CONTAINMENT BARRIER ALTERNATIVES

Five remedial alternatives were assembled for the Upland Areas based on process options remaining from the technology screening process and site-specific conditions. The alternatives assembled for the Upland Areas are as follows:

- Alternative 1─No Action
- Alternative 2─Institutional Controls, Hot Spot Removal (Hazard Quotient [HQ] = 10), Groundwater Monitoring and 2-Foot Soil Cover
- Alternative 3─Institutional Controls, Hot Spot Removal (HQ = 5), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 4─Institutional Controls, Hot Spot Removal (HQ = 3), Groundwater Monitoring, and a 2-Foot Soil Cover
- Alternative 5─Institutional Controls, Debris Excavation, and Groundwater Monitoring

4.2.1 Alternative 1─No Action

CERCLA requires the "No Action" alternative to be carried forward to the detailed analysis phase in order to provide a baseline comparison with the other alternatives. The "No Action" alternative implies that no remedial action would be undertaken within the Upland Areas of IA-H1.

4.2.2 Alternative 2─Institutional Controls, Hot Spot Removal (HQ=10), Groundwater Monitoring, and 2-Foot Soil Cover

4.2.2.1 Institutional Controls

Land use restrictions will be placed on the IA-H1 property to prohibit the development of the land for unauthorized uses. Per the Mare Island Final Reuse Plan, future land use at IA-H1 includes recreational use and open space (City of Vallejo, California, 1994). The following land use restrictions will be placed on the site as deed restrictions:

- Future reuse of the property will prohibit residences, schools, daycare centers, or hospitals
- None of the following activities will be conducted unless the California Department of Toxic Substances (DTSC) gives approval:
- Covering or disturbing of groundwater wells in a manner that restricts access to groundwater wells
- Alteration of groundwater conditions through activities such as groundwater pumping
- No soil/sediment disturbing activities by the public will be permitted
- Education and awareness programs will be implemented in the local community

Confirmation that the land use restrictions are maintained will be monitored visually during quarterly site inspections. During the inspections, the site will be assessed as to whether the land use restrictions have been violated. The area will be inspected quarterly to verify that no buildings or structures have been built at the site, no unauthorized wells have been installed, all groundwater wells are locked and in good condition, and that there have been no excavations or other subsurface activities at the site.

The DON's intention is to pursue title transfer of IA-H1 to an interested party or parties, including reversion to the State. Prior to a title transfer, the monitoring and enforcement of land use restrictions and institutional controls specified in the Remedial Action Plan (RAP)/Record of Decision (ROD)/RCRA Closure Plan will be incorporated into the Post-Closure/Post-Remedy Operations and Maintenance (O&M) Plan. This work will be performed by WESTON in accordance with the existing Environmental Services Cooperative Agreement. In the event all or a portion of IA-H1 are transferred or leased, the deed or Finding of Suitability to Lease will incorporate applicable land use restrictions and institutional controls.

4.2.2.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Upland Areas that exceed a human health cancer risk estimate of $1x10^{-5}$ (leaving in place only materials that are on the order of 10^{-5} or better) a human health Hazard Index (HI) of 1 for noncancer adverse health effects, threats to groundwater, locations exhibiting visible oil or free product, and areas presenting an ecological risk based on the high Toxicity Reference Value (TRV) with a HQ of 10. Table 4-1 presents a summary of the identification of hot spot areas based on the aforementioned risk-based criteria as developed in Section 3 of this report. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-1. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total polychlorinated biphenyls (PCBs), and benzo[a]pyrene for human health; and copper, lead, selenium, zinc, total PCBs, and total dichlorodiphenyltrichloroethanes [DDTs] for ecological receptors) exceeded the criteria; if free product was observed at the location; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-5 presents the hot spot

locations for this alternative and chemical concentrations present at these locations. Figure 4-6 presents the components of the alternative.

The hot spot extent of contamination at a single, isolated sample point was conservatively estimated as a 50 by 50 foot area. Other hot spot boundaries were determined as the mid-point distance between a sample location that exceeded hot spot criteria and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-2.

For areas exhibiting free product, an investigation of the extent of the oil/product would be conducted during excavation of these free product hot spot areas in order to correctly delineate the presence of oil/free product and refine the area and volume of contamination.

As shown in Table 4-2, the estimated *in-situ* volume of the hot spots within the Upland Areas is approximately 46,880 cubic yards. Confirmation samples will be collected from each 50 by 50 foot excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation. The hot spot areas will then be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will be consolidated on site within the Containment Area. The estimated quantity of backfill required for hot spot areas is 53,870 cubic yards including a factor of plus 15 percent to account for compaction.

Soil will be removed with a hydraulic excavator and loaded into an off-road dump truck for transport to the Containment Area. The soil will be spread in 1 foot lifts and compacted using a large sheepsfoot vibrating compactor. Borrow soil used for backfilling the excavations will be similarly loaded, transported to the excavation site, spread, and compacted. The time to complete this task is approximately 2 months.

4.2.2.3 Groundwater Monitoring

Groundwater monitoring in the shallow water bearing zone (SWBZ) will be conducted at the margins of the Upland Areas near the Non-Tidal Wetland Areas. Migration of shallow groundwater to the Non-Tidal Wetland Areas is a potential concern. Implementation of a hot spot removal option should decrease the potential for contamination to move into the groundwater. The groundwater quality will be evaluated to ensure groundwater from the Upland Areas is not impacting the Non-Tidal Wetland Areas. Approximately three monitoring wells will be installed in appropriate locations at the margins of the Upland Areas. Groundwater will be monitored for COCs for a planned 30 years. During the 5-year review, if the wells show that contaminants are not moving into the wetlands, the monitoring requirement will be re-evaluated. Continued monitoring, if required, will be re-evaluated during the next 5-year review.

4.2.2.4 2-Foot Soil Cover

The 2-foot soil cover involves placement of a 2 feet deep soil cover over Upland Areas, including all hot spot areas that have been refilled to their original levels. Details describing the placement of the 2-foot soil cover to ensure a minimum 2-foot cover is achieved will be presented in the Remedial Design Plan. Upland Areas include the Demolition Debris Subarea, Northwest Dump Road Subarea, Fire-Fighting Training Subarea, IR 16 and Pond 1. The total *in-situ* volume of the soil cover is estimated at 120,000 cubic yards. The area of the soil cover is 1,620,000 square feet. The cover soil is “clean” soil and is tested to ensure that it meets acceptable standards. Because the cover soil contains less arsenic than the ambient/background Mare Island levels, the risk posed by areas containing the 2-foot soil cover will be less than that in the remainder of Mare Island ambient/background levels. The soil cover will be graded and hydroseeded to provide an adequate base for vegetative growth, which will have the added

benefit of reducing particulate transport to the low-lying wetland areas of IA-H1. The hydroseeding and resultant plant growth will help to reduce any soil erosion. Areas previously excavated and backfilled with at least 2 feet of soil cover will receive an additional 2-foot cover as part of this remedy.

The principle causes of erosion are rainfall and runoff. The resulting erosion can be estimated using the Universal Soil Loss Equation (USLE), which was developed to estimate long-term average annual soil loss The factors used in the USLE include soil erodibility, slope length and steepness (LS), and cover management practices. A conservative LS factor of 0.66 was chosen based on a 150 foot long slope at 5 percent, which resulted in a soil loss value of 0.03 tons per acre per year, which is far less than the allowable standard for adequate erosion control of 2 tons per acre per year. The 2-foot soil cover will also provide a barrier for any MEC materials or radiological items (if present). The 2-foot cover will also provide a barrier to exclude current ecological receptors from any remaining contamination. The total *in-situ* volume of the soil cover is estimated at 120,000 cubic yards. The area of the soil cover is 1,620,000 square feet.

4.2.2.5 Wetland Mitigation

Wetland mitigation is related to the Containment Area alternatives; however, the Upland Areas will be used to make the new wetlands. Wetland mitigation includes creation of approximately 8.2 acres of pickleweed/wetland areas in the northwest upland portion of IA-H1 to compensate for the loss of existing degraded wetlands habitat covered by the Containment Area cap. The Wetland Creation Areas 1 through 5, depicted in Figure 4-6, will be graded to appropriate elevations (approximately 8 feet above mean sea level [amsl]) to allow for soil saturation and/or inundation that resemble the current hydrological regime of the adjacent existing wetlands. Achieving these hydrological conditions will promote the establishment of pickleweed marsh vegetation, which is preferred by the salt marsh harvest mouse, a Federal and State endangered species. See the Containment Area discussion of Wetland Mitigation (Section 4.1.2.2) for further information.

4.2.2.6 Green Sand Excavation in Northwest Dump Road Subarea

A Green Sand Area is visible on the soil surface within the Northwest Dump Road Subarea (Figure 4-6). The approximate dimensions of the Green Sand Area are 100 feet by 100 feet. The surface soil and visible green sand will be removed and samples taken and analyzed prior to backfilling. An estimated 185 cubic yards of soil and green sand will require excavation and disposal. This area will be backfilled to grade following excavation activities. A 2-foot soil cover will be placed over this area.

4.2.2.7 Asbestos Soil Cover in Pond 1

Small amounts of asbestos-containing materials are visible within the portion of Dredge Pond 1 inside IA-H1. The 2-foot soil cover described in Section 4.2.2.4 will provide an effective barrier against potential exposure to these materials.

4.2.3 Alternative 3—Institutional Controls, Hot Spot Removal (HQ=5), Groundwater Monitoring, and 2-Foot Soil Cover

4.2.3.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Upland Areas Alternative 3.

4.2.3.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Upland Areas that exceed a human health cancer risk estimate of $1x10^{-5}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, locations exhibiting visible oil or free product, and areas presenting an ecological risk based on the high TRV with a HQ of 5. Table 4-4 presents a summary of the identification of hot spot areas based on the aforementioned risk-based criteria as developed in Section 3 of this report. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-4. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and copper, lead, selenium, zinc, total PCBs, and total DDTs

for ecological receptors) exceeded the criteria; if free product was observed at the location; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-7 presents the hot spot locations for this alternative and chemical concentrations present at these locations. Figure 4-8 presents the components of the alternative.

The hot spot extent of contamination at a single, isolated sample point was conservatively estimated as a 50 by 50 foot area. Other hot spot boundaries were determined as the mid-point distance between a sample location that exceeds hot spot criteria and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-5.

For areas exhibiting free product, an investigation of the extent of the oil/product will be conducted during excavation of these free product hot spot areas in order to correctly delineate the presence of oil/free product and refine the area and volume of contamination.

As shown in Table 4-5, the estimated *in-situ* volume of the hot spots within the Upland Areas is approximately 47,450 cubic yards. Confirmation samples will be collected from each 50 by 50 foot excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation. The hot spot areas will then be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will be consolidated on site within

the Containment Area. The estimated quantity of backfill required for hot spot areas is 54,515 cubic yards including a factor of plus 15 percent to account for compaction.

4.2.3.3 Groundwater Monitoring

The discussion in Section 4.2.2.3 applies equally to Upland Areas Alternative 3.

4.2.3.4 2-Foot Soil Cover

The discussion in Section 4.2.2.4 applies equally to Upland Areas Alternative 3.

4.2.3.5 Green Sand Excavation in Northwest Dump Road Subarea

The discussion in Section 4.2.2.6 applies equally to Upland Areas Alternative 3.

4.2.3.6 Asbestos Soil Cover in Pond 1

The discussion in Section 4.2.2.7 applies equally to Upland Areas Alternative 3.

4.2.4 Alternative 4—Institutional Controls, Hot Spot Removal (HQ=3), Groundwater Monitoring, and 2-Foot Soil Cover

4.2.4.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Upland Areas Alternative 4.

4.2.4.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Upland Areas that exceed a human health cancer risk estimate of $1x10^{-5}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, locations exhibiting visible oil or free product, and areas presenting an ecological risk based on the high TRV with a HQ of 3. Table 4-6 presents a summary of the identification of hot spot areas. A single set of comparison criteria are used for remediation in the upland habitat. The criteria are based on a tiered process of first comparing values of individual

ecological receptors, then comparing the selected value to human health and threat to groundwater values, and finally comparing the new selected value to a statistical value for ambient/background. The "average threshold" ecological risk-based average values by chemical for the upland habitat are the lowest value across all receptors with the high TRV HQ 3 for the Western meadowlark, California vole, ornate shrew, gray fox and northern harrier. For each chemical, the lowest number among the ecological average threshold, human health, and threat to groundwater criteria is compared to the 95th percentile of the ambient/background dataset, and the higher of the two numbers is selected. This final value will be compared to the existing concentration results at individual locations to identify hot spots for excavation and the subsequent confirmation sample results to determine if further excavation is required. The subsequent placement of clean fill (a minimum of 2 feet) will occur over the entire upland habitat and is not dependant on residual concentrations. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-6. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and copper, lead, selenium, zinc, total PCBs, and total DDTs for ecological receptors) exceeded the criteria; if free product was observed at the location; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-9 presents the hot spot locations for this alternative and chemical concentrations present at these locations. Figure 4-10 presents the components of the alternative.

The hot spot extent of contamination at a single, isolated sample point was conservatively estimated as a 50 by 50 foot area. Other hot spot boundaries were determined as the mid-point distance between a sample location that exceeded hot spot criteria and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-7.

For areas exhibiting free product, an investigation of the extent of the oil/product will be conducted during excavation of these free product hot spot areas in order to correctly delineate the presence of oil/free product and refine the area and volume of contamination.

As shown in Table 4-7, the estimated *in-situ* volume of the hot spots within the Upland Areas is approximately 54,490 cubic yards. Confirmation samples will be collected from each 50 by 50 foot excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. The hot spot areas will then be backfilled to existing grade with soil from a suitable borrow source. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation. The excavated soil will be consolidated on site. The estimated quantity of backfill required for hot spot areas is 62,600 cubic yards including a factor of plus 15 percent to account for compaction.

4.2.4.3 Groundwater Monitoring

The discussion in Section 4.2.2.3 applies equally to Upland Areas Alternative 4.

4.2.4.4 2-Foot Soil Cover

The discussion in Section 4.2.2.4 applies equally to Upland Areas Alternative 4.

4.2.4.5 Green Sand Excavation in Northwest Dump Road Subarea

The discussion in Section 4.2.2.6 applies equally to Upland Areas Alternative 4.

4.2.4.6 Asbestos Soil Cover in Demolition Debris Subarea and Pond 1

The discussion in Section 4.2.2.7 applies equally to Upland Areas Alternative 4 with the addition of the Demolition Debris Subarea excavation.

4.2.5 Alternative 5—Debris Excavation and Groundwater Monitoring

4.2.5.1 Upland Debris Excavation

This Alternative 5 includes excavation of all upland fill material within the Demolition Debris Subarea, Northwest Dump Road Subarea, Fire-Fighting Training Subarea, Solid Waste Disposal/Lead Oxide Storage and Disposal Subarea, and the Upland Areas of the West Subarea (Pond 1). Figure 4-11 presents the hot spot locations that exceed a human health cancer risk estimate of $1x10^{-4}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, locations exhibiting visible oil or free product, and areas presenting an ecological risk based on the high TRV with a HQ of 1. Since these hot spot areas are wide-spread throughout the Upland Areas, this alternative includes excavation of all fill areas rather than just hot spot locations (Figure 4-11). Figure 4-12 presents the components of the alternative.

The area of the Demolition Debris Subarea, excluding the proposed mitigated wetland area within this subarea, is approximately 5.6 acres. The depth of the debris ranges from 2 to 14 feet bgs. The estimated *in-situ* quantity of debris and fill material at the Demolition Debris Subarea is 63,230 cubic yards.

The area of the Fire-Fighting Training Subarea, excluding the existing and proposed wetland areas within this subarea, is approximately 5.7 acres. The depth of the debris ranges from 2 to 8 feet bgs. The estimated *in-situ* quantity of debris and fill material at the Fire-Fighting Training Subarea is 45,985 cubic yards.

The area of the Northwest Dump Road Subarea, excluding the existing and proposed wetland areas within this subarea, is approximately 8.8 acres. The depth of the debris ranges from 10 to 16 feet bgs. The estimated *in-situ* quantity of debris and fill material at the Northwest Dump Road Subarea is 184,580 cubic yards.

The area of the Upland Areas within the West Subarea (Pond 1) is approximately 5.1 acres. The depth of the debris ranges from 5 to 7 feet bgs. The estimated *in-situ* quantity of debris and fill material at the Upland Areas within the West Subarea (Pond 1) is 49,370 cubic yards.

The area of the Solid Waste Disposal/Lead Oxide Storage and Disposal Subarea is approximately 8.6 acres. The depth of the debris ranges from 6 to 12 feet bgs. The estimated *in-situ* quantity of debris and fill material at the Solid Waste Disposal/Lead Oxide Storage and Disposal Subarea is 110,665 cubic yards. A portion of the fill area may be salvaged from the clean fill placed during the removal action at Installation Restoration (IR) Area 16.

As shown in Table 4-9, the total estimated *in-situ* volume of the debris within the Upland Areas is 453,850 cubic yards. The areas will be backfilled to a grade of about 8.5 to 9 feet amsl and the excavated soil would be disposed of on site within the Containment Area. All excavated areas will be graded and hydroseeded.

4.2.5.2 Groundwater Monitoring

The discussion in Section 4.2.2.3 applies to Upland Areas Alternative 5 in a limited manner. Because the debris will be fully removed, there will not be a continuing source of contamination. The only reason to monitor groundwater in this area is to monitor any contamination that is already in the groundwater.

4.2.5.3 Green Sand Excavation in Northwest Dump Road Subarea

The discussion in Section 4.2.2.6 applies equally to Upland Areas Alternative 5.

4.2.5.4 Asbestos Soil Cover in Demolition Debris Subarea and Pond 1

The discussion in Section 4.2.2.7 applies equally to Upland Areas Alternative 5 with the addition of the Demolition Debris Subarea excavation.

4.3 NON-TIDAL WETLAND AREAS OUTSIDE THE CONTAINMENT BARRIER ALTERNATIVES

Five remedial alternatives were assembled for the Non-Tidal Wetland Areas based on process options remaining from the technology screening process and site-specific conditions. The alternatives assembled for the Non-Tidal Wetland Areas are as follows:

- Alternative 1—No Action
- Alternative 2—Institutional Controls, Hot Spot Removal (HQ = 10), and Monitoring
- Alternative 3—Institutional Controls, Hot Spot Removal (HQ = 5), and Monitoring
- Alternative 4—Institutional Controls, Hot Spot Removal (HQ = 3), and Monitoring
- Alternative 5—Institutional Controls, Hot Spot Removal (HQ = 1), and Monitoring

4.3.1 Alternative 1—No Action

CERCLA requires the "No Action" alternative to be carried forward to the detailed analysis phase in order to provide a baseline comparison with the other alternatives. The "No Action" alternative implies that no remedial action will be undertaken within the Non-Tidal Wetland Areas of IA-H1.

4.3.2 Alternative 2—Institutional Controls, Hot Spot Removal (HQ=10), and Monitoring

4.3.2.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Non-Tidal Wetland Areas Alternative 2.

4.3.2.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas that exceed a human health cancer risk estimate of $1x10^{-4}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, and areas presenting an ecological risk based on the high TRV with a HQ of 10. Table 4-11 presents a summary of the identification of hot spot areas based on the aforementioned risk-based criteria as developed in Section 3 of this report. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-11. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and antimony, lead, selenium, and total PCBs for ecological receptors) exceeded the criteria; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-13 presents the hot spot locations for this alternative and

chemical concentrations present at these locations. Figure 4-14 presents the components of the alternative.

The extent of contamination at a single point area was conservatively estimated as a 50 by 50 foot area. Other areas were determined as a distance between a contaminated sample location and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-12.

As shown in Table 4-12, the estimated *in-situ* volume of the hot spots within the Non-Tidal Wetland Areas is approximately 1,495 cubic yards. Confirmation samples will be collected from each excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. The hot spot areas will be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will be consolidated on site within the Containment Area. The estimated quantity of backfill required for hot spot areas is 1,715 cubic yards including a factor of plus 15 percent to account for compaction. The estimated volume of soil for on-site disposal is 1,715 cubic yards (2,575 tons). All excavated wetland areas will be restored.

Soil will be removed with a hydraulic excavator and loaded into an off-road dump truck for transport to the Containment Area. The soil will be spread in 1 foot lifts and compacted using a large sheepsfoot vibrating compactor. Borrow soil used for backfilling the excavations will be similarly loaded, transported to the excavation site, spread, and compacted. Confirmation sampling will be completed for each 50 by 50 foot excavation area to ensure the COCs have been removed. Excavation will continue until the criteria set out in the Wetland Mitigation Plan (LSA, 2005b) are met or excavation has reached 3 feet below target grade. In the event that

contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation.

A monitoring program to show the performance of the remedial action will be developed as part of the remedial design. Summary reports will be prepared documenting the results of the monitoring program. Monitoring will document that the exposure risks to ecological receptors remain limited or decrease over the long term. Monitoring programs will be evaluated for any changes required during the 5-year review.

4.3.3 Alternative 3—Institutional Controls, Hot Spot Removal (HQ=5), and Monitoring

4.3.3.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Non-Tidal Wetland Areas Alternative 3.

4.3.3.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas including areas that exceed a human health cancer risk estimate of $1x10^{-4}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, and areas presenting an ecological risk based on the high TRV with a HQ of 5. Table 4-13 presents a summary of the identification of hot spot areas based on the aforementioned risk-based criteria as developed in Section 3 of this report. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-13. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and antimony, lead, selenium, and total PCBs for ecological receptors) exceeded the criteria; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-15 presents the hot spot locations for this alternative and chemical concentrations present at these locations. Figure 4-16 presents the components of the alternative.

The extent of contamination at a single point area was conservatively estimated as a 50 by 50 foot area. Other areas were determined as a distance halfway between a contaminated sample location and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-14.

As shown in Table 4-14, the estimated *in-situ* volume of the hot spots within the Non-Tidal Wetland Areas is approximately 2,100 cubic yards. Confirmation samples will be collected from each excavation area after soil removal prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1.The hot spot areas will then be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will be consolidated on site. The estimated quantity of backfill required for hot spot areas is 2,410 cubic yards including a factor of plus 15 percent to account for compaction.

Soil will be removed with a hydraulic excavator and loaded into an off-road dump truck for transport to the Containment Area. The soil will be spread in 1 foot lifts and compacted using a large sheepsfoot vibrating compactor. Borrow soil used for backfilling the excavations will be similarly loaded, transported to the excavation site, spread, and compacted. Confirmation sampling will be completed for each 50 by 50 foot area to ensure the COCs have been removed. Excavation will continue until the criteria set out Wetland Mitigation Plan (LSA, 2005b) are met or excavation has reached 3 feet below target grade. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation.

4.3.3.3 Monitoring

The discussion in Section 4.3.2.3 applies equally to Non-Tidal Wetland Areas Alternative 3.

4.3.4 Alternative 4—Institutional Controls, Hot Spot Removal (HQ=3), and Monitoring

4.3.4.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Non-Tidal Wetland Areas Alternative 4.

4.3.4.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas including areas that exceed a human health cancer risk estimate of $1x10^{-4}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, and areas presenting an ecological risk based on the high TRV with a HQ of 3. Table 4-15 presents a summary of the identification of hot spot areas based on the aforementioned risk-based criteria as developed in Section 3 of this report. All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-15. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and antimony, lead, selenium, and total PCBs for ecological receptors) exceeded the criteria; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-17 presents the hot spot locations for this alternative and chemical concentrations present at these locations. Figure 4-18 presents the components of the alternative.

The extent of contamination at a single point area was conservatively estimated as a 50 by 50 foot area. Other areas were determined as a distance between a contaminated sample location and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the

boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-16.

As shown in Table 4-16, the estimated *in-situ* volume of the hot spots within the Non-Tidal Wetland Areas is approximately 2,825 cubic yards. Confirmation samples will be collected from each excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. The hot spot areas will be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will then be consolidated on site within the Containment Area. The estimated quantity of backfill required for hot spot areas is 3,240 cubic yards including a factor of plus 15 percent to account for compaction.

Soil will be removed with a hydraulic excavator and loaded into an off-road dump truck for transport to the Containment Area. The soil will be spread in 1 foot lifts and compacted using a large sheepsfoot vibrating compactor. Borrow soil used for backfilling the excavations will be similarly loaded, transported to the excavation site, spread, and compacted. Confirmation sampling will be completed for each 50 by 50 foot area to ensure the COCs have been removed. Excavation will continue until the criteria set out in the Wetland Mitigation Plan (LSA, 2005b) are met or excavation has reached 3 feet below target grade. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation.

4.3.4.3 Monitoring

The discussion in Section 4.3.2.3 applies equally to Non-Tidal Wetland Areas Alternative 4.

4.3.5 Alternative 5—Institutional Controls, Hot Spot Removal (HQ=1), and Monitoring

4.3.5.1 Institutional Controls

The discussion in Section 4.2.2.1 applies equally to Non-Tidal Alternative 5.

4.3.5.2 Hot Spot Removal

This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas including areas that exceed a human health cancer risk estimate of $1x10^{-5}$ (leaving in place only materials that are on the order of 10^{-5} or better), a human health HI of 1 for noncancer adverse health effects, threats to groundwater, and areas presenting an ecological risk based on the high TRV with a HQ of 1. Table 4-17 presents a summary of the identification of hot spot areas.

Two sets of criteria are used for remediation in the non-tidal wetland habitats, the "average" and "upper" thresholds. Both sets of criteria are based on a tiered process of first comparing values protective of individual ecological receptors, then comparing the selected ecological value to human health and threat to groundwater values, and finally comparing the final selected value to a statistical value for ambient/background.

The two thresholds differ in that the average threshold includes the low TRV HQ of one for the salt marsh harvest mouse (SMHM) and the 95th percentile of the ambient/background dataset, whereas the upper threshold includes the high TRV HQ of one for SMHM and the maximum value of the ambient/background dataset (with three exceptions).

The "average threshold" ecological risk-based average values by chemical for the non-tidal wetland are the lowest value across all receptors with the high TRV HQ of one for killdeer, mallard (breeding and non-breeding), great blue heron, the gray fox, and the northern harrier, and the low TRV HQ of one for salt marsh harvest mouse (SMHM). For each chemical, the lowest number among the ecological average threshold, human health, and threat to groundwater criteria is compared to the 95th percentile of the ambient/background dataset, and the higher of the two numbers is selected as the average threshold. This final value will be compared to the 95UCL of the residual database that includes all sample locations still in place, the new confirmation samples, and the characterization samples for the fill material (which would replace those from

excavated locations). If the 95UCL of the residual data exceeds the final average threshold criterion, then an iterative process of excluding individual locations and recalculating the 95UCL would occur until the revised 95UCL was below the average threshold. Then additional excavation at those locations would occur, the subsequent confirmation samples be added to the residual database, and a new 95UCL would be calculated.

The "upper threshold" ecological risk-based values by chemical for the non-tidal wetland are the lowest value across all receptors with the high TRV HQ of one for killdeer, mallard (breeding and non-breeding), great blue heron, the gray fox, and the northern harrier, and the SMHM. For each chemical, the lowest number among the ecological upper threshold, human health, and threat to groundwater criteria is compared to the maximum (99th percentile) of the ambient/background dataset, and the higher of the two numbers is selected.

This final upper threshold value will be compared to the existing concentration results at individual locations to identify hot spots for excavation and the subsequent confirmation sample results to determine if further excavation is needed there. Excavation at individual locations may also be needed to reduce the overall 95UCL of the residual data as described above.

For three chemicals (chromium, manganese, mercury), the high TRV HQ of one based ecological criterion for the most sensitive receptor was lower than the human health and threat to groundwater values, and was also lower than the 95th percentile and maximum ambient/background values. Additional evaluation of the relative concentrations and locations in the marsh for each sample was done for these chemicals as described below.

For chromium, the high TRV HQ of one value for killdeer (17.7 mg/kg) was the lowest value of the ecological, human health, and threat to groundwater criteria. The 95th percentile and maximum values of the ambient/background dataset for chromium are 140 and 148 mg/kg, respectively. Twenty-five samples have chromium concentrations above 148 mg/kg with a maximum of 257 mg/kg. Eight locations were identified as hot spots based on other chemicals (IR01HA036, IR01HA009, IR01HA013, IR16SS430, IR16SS424, IR01HA018, IR16SS406, and IR16SS435). All the other locations with concentrations above 148 mg/kg chromium located within 150 feet of an upland area or a proposed excavation area were included as hot spot areas to be excavated (IR16SS450, IR16SS407, IR16SS408, IR16SS451, IR16SS431, IR01HA003,

IR01HA001, IR01HA014, IR01HA015, IR01HA008, IR01HA002, IR01HA004, IR01HA011, IR01HA012, IR01HA016, and IR02GB016).

For manganese and mercury, the maximum values from the ambient/background dataset were anomalously high at 13,559 and 69.7 mg/kg, respectively. Therefore, the 95th percentile ambient/background values (1600 and 2 mg/kg, respectively) were used as the comparator. However, several wetland locations that had mercury or manganese concentrations greater than the 95th percentile ambient/background values were not proposed for excavation, because they were individual sample locations located at least 150 feet from an adjacent upland edge or an identified hot spot excavation area. The resource trustees identified these exceptions based on best professional judgment of the benefit of removing that isolated contamination compared with the impact of accessing and removing it. For manganese, six locations had manganese concentrations above 1,600 mg/kg with a maximum of 4,810 mg/kg. Three locations were identified as hot spots based on other chemicals (WETBSD050, IR01GB095 and WETBSD032), two were added as hot spots and are near an upland edge or other excavation area (WETASD012 and WETBSD033), and one isolated location will be left in place due to distance from an adjacent upland or a proposed excavation area (H-14 in Wetland D). For mercury, seven locations had concentrations exceeding 2 mg/kg with a maximum of 5.1 mg/kg. One location was identified as a hot spot based on other chemicals (WETBSD050), three were added as hot spots and were near an adjacent upland or a proposed excavation area (WETBSD053, WETBSD035, and WETBSD036), and two isolated locations will be left in place based on distance from an adjacent upland or a proposed excavation area (WETASD005 and WETBSD030). Flowcharts demonstrating the above hot spot excavation decision logic are shown in Figure 4-19.

All chemical concentrations were compared to the hot spot criteria developed for each exposure depth and are presented in Table 4-17. A sample location was retained and included in the alternative if the chemical concentration of at least one risk driver (arsenic, total PCBs, and benzo[a]pyrene for human health; and antimony, lead, selenium, and total PCBs for ecological receptors) exceeded the criteria; if a chemical concentration presented a threat to groundwater; and/or if a chemical outlier presented a risk. Figure 4-20 presents the hot spot locations for this

alternative and chemical concentrations present at these locations. Figure 4-21 presents the components of the alternative.

The extent of contamination at a single point area was conservatively estimated as a 50 by 50 foot area. Other areas were determined as a distance halfway between a contaminated sample location and one in which chemical concentrations were below hot spot criteria. The depth of contamination for areas presenting an ecological risk was estimated at 2 feet bgs (the assumed exposure depth for ecological receptors). The depth of contamination for areas exhibiting free product was estimated at the lowest depth where free product was observed as described on the boring logs. The depth of contamination in areas presenting a human health risk in subsurface soils was estimated at approximately 1 foot deeper than the contaminated sample depth or at 10 feet bgs (the maximum exposure depth for human receptors), whichever is shallower. The areas, depths, and volume of soil to be removed at each hot spot area are presented in Table 4-18.

As shown in Table 4-18, the estimated *in-situ* volume of the hot spots within the Non-Tidal Wetland Areas is approximately 25,420 cubic yards. Confirmation samples will be collected from each excavation area after soil removal and prior to backfilling. The number of samples and specific sampling details will be prepared during the design phase and included in the Remedial Design Plan. Samples will be analyzed for all risk drivers within IA-H1. The hot spot areas will then be backfilled to existing grade with soil from a suitable borrow source. The excavated soil will be consolidated on site within the Containment Area. The estimated quantity of backfill required for hot spot areas is 29,205 cubic yards including a factor of plus 15 percent to account for compaction.

Soil will be removed with a hydraulic excavator and loaded into an off-road dump truck for transport to the Containment Area. The soil will be spread in 1 foot lifts and compacted using a large sheepsfoot vibrating compactor. Borrow soil used for backfilling the excavations will be similarly loaded, transported to the excavation site, spread, and compacted. Confirmation sampling will be completed for each 50 by 50 foot area to ensure the COCs have been removed. Excavation will continue until the criteria set out in the Wetland Mitigation Plan (LSA, 2005b) are met or excavation has reached 3 feet below target grade. In the event that contaminant concentrations at the base of an excavation exceed shallow cleanup criteria, the Navy will

immediately notify DTSC and obtain from DTSC timely direction regarding the possible need for further excavation, based on threat to human health or the environment, or completion of hot spot excavation..

4.3.5.3 Monitoring

The discussion in Section 4.3.2.3 applies equally to Non-Tidal Wetland Areas Alternative 5.

5. DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Based on the evaluation of process options with respect to effectiveness, implementablity, and cost criteria (Section 3), and the development of alternatives using the retained process options and site-specific conditions (Section 4), the following alternatives were identified for detailed analysis for the Investigation Area H1 (IA-H1) area:

Containment Area

- Alternative 1─No Action
- Alternative 2A─Variable Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring
- Alternative 2B─Resource Conservation and Recovery Act (RCRA) Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring
- Alternative 3─Removal and Disposal

Upland Areas outside the Containment Barrier

- Alternative 1─No Action
- Alternative 2─Institutional Controls, Hot Spot Removal (Hazard Quotient [HQ]=10), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 3─Institutional Controls, Hot Spot Removal (HQ=5), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 4─Institutional Controls, Hot Spot Removal (HQ=3), Groundwater Monitoring, and 2-Foot Soil Cover
- Alternative 5─Debris Excavation and Groundwater Monitoring

Non-Tidal Wetland Areas outside the Containment Barrier

- Alternative 1─No Action
- Alternative 2─Institutional Controls, Hot Spot Removal (HQ=10), and Monitoring
- Alternative 3─Institutional Controls, Hot Spot Removal (HQ=5), and Monitoring
- Alternative 4─Institutional Controls, Hot Spot Removal (HQ=3), and Monitoring
- Alternative 5─Institutional Controls, Hot Spot Removal (HQ=1), and Monitoring

In this section, these alternatives are evaluated based on the following nine criteria as required by Section 300.430(e) of the National Contingency Plan (NCP):

Threshold Criteria

1. Overall protection of human health and the environment
2. Compliance with ARARs

Balancing Criteria

3. Long-term effectiveness and permanence
4. Reduction in toxicity, mobility, or volume
5. Short-term effectiveness
6. Implementability
7. Cost

Modifying Criteria

8. State acceptance
9. Community acceptance

Overall Protection of Human Health and the Environment

Overall protection of human health and the environment is a threshold criterion that must be met by the selected alternative. This criterion assesses whether each alternative provides adequate protection of human health and the environment. The overall assessment of the protection draws on the assessment of other evaluation criteria including long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. The protectiveness evaluation focuses on risk reduction or elimination for each alternative. Risk reductions are associated with how effectively an alternative meets the Remedial Action Objectives (RAOs).

Compliance with ARARs

This criterion is used to evaluate whether each alternative will meet all identified federal and state ARARs or whether justification exists for waiving one or more ARARs.

Long-Term Effectiveness and Permanence

Each alternative is evaluated in terms of risk remaining at the site after RAOs have been met. The primary focus of this evaluation is the extent and effectiveness of controls used to manage the risk posed by treatment residuals or untreated wastes. The following factors are considered to determine long-term effectiveness and permanence:

- Adequacy of mitigative controls
- Reliability of mitigative controls
- Magnitude of the residual risk

Reduction in Toxicity, Mobility, or Volume

This evaluation criterion addresses the statutory preference for treatment options that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. This preference is satisfied when treatment reduces the principal threats through the following:

- Destruction of toxic contaminants
- Reduction in contaminant mobility
- Reduction of the total mass of toxic contaminants
- Reduction of total volumes of contaminated media

Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until the RAOs are met. Under this criterion, alternatives are evaluated on their effects on human health and the environment during the implementation of the remedial action. The following factors are considered:

- Exposure of the community during implementation
- Exposure of workers during construction
- Environmental impacts
- Time to achieve RAOs

Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. The following factors were considered:

- Ability to construct the technology
- Reliability of the technology
- Monitoring considerations
- Availability of equipment and specialists
- Ability to obtain approvals from regulatory agencies
- Cost

The cost analysis for each alternative is based on estimates of capital and operation and maintenance (O&M) costs. Capital costs consist of direct and indirect costs. Direct costs include the purchase of equipment, labor, and materials necessary to implement the alternative. Indirect costs include engineering, financial, and other services such as testing and monitoring. Annual O&M costs for each alternative include operating labor, maintenance materials and labor, auxiliary materials, and energy.

The post-closure O&M period is assumed to be a minimum of 30 years based on landfill post-closure requirements.

State and Community Acceptance

These two criteria evaluate the issues and concerns of the State and community regarding each alternative. These criteria cannot be fully evaluated until the state and community have reviewed the alternatives, which will occur after submittal of the proposed plan. However, the United States Department of the Navy (DON) has performed a preliminary evaluation of these criteria based on past state and community acceptance of alternatives for similar sites and initial discussions with the Restoration Advisory Board (RAB).

5.1 CONTAINMENT AREA

5.1.1 Alternative 1—No Action

Under this alternative, no action is taken to alter the areas within the Containment Area; current maintenance activities required under the interim status permit for the RCRA Landfill would continue.

5.1.1.1 Overall Protection of Human Health and the Environment

This alternative does not contain and isolate all the landfill refuse. The interim status RCRA Landfill would require continuing maintenance; however, in other areas no action could result in refuse being exposed by erosion. It does not provide for reduction or elimination of infiltration and impacts on groundwater, nor does it provide protection for human health and the environment.

The "No Action" alternative does not provide protection of human health and the environment and does not meet all RAOs.

5.1.1.2 Compliance with ARARs

This action will not comply with all of the action-specific ARARs relating to groundwater and closure of landfills. Several location-specific ARARs may not be met under the "No Action" alternative. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.1.1.3 Long-Term Effectiveness

The "No Action" alternative will not provide long-term protection because no contaminant reduction, removal, or containment measures are implemented to protect human and ecological receptors. Direct contact with refuse or contaminated dusts may become possible if refuse in the Facility Landfill and remaining portions of the Containment Area, excluding the RCRA Landfill, is exposed through deterioration of the existing cover. The "No Action" alternative does not

eliminate the direct exposure pathway. Therefore, human health and ecological risks may continue to exist or worsen over time with the "No Action" alternative for landfill refuse.

The "No Action" alternative does not provide any remedy for potential movement of contaminated groundwater or reduction of recharge through the landfill. The "No Action" alternative does not effectively reduce the long-term risk potential posed at the site.

5.1.1.4 Reduction of Toxicity, Mobility, or Volume

The "No Action" alternative will not result in a reduction in toxicity, mobility, or volume of landfill refuse, leachate, or landfill gas, except for reductions due to natural attenuation.

5.1.1.5 Short-Term Effectiveness

The "No Action" alternative will not have any short-term impacts, as it does not involve remediation activities.

5.1.1.6 Implementability

The "No Action" alternative is readily implementable, however it does not meet the RAOs.

5.1.1.7 Cost

There is no direct cost associated with the "No Action" alternative.

5.1.1.8 State Acceptance

The "No Action" alternative may not be acceptable by the State because it does not provide long-term protection of human health and the environment. The potential for contaminants from the site to migrate off site and affect human and ecological receptors will not be reduced or controlled under this alternative. State acceptance will be further evaluated following the public comment period.

5.1.1.9 Community Acceptance

The public may not find the "No Action" alternative acceptable because it does not provide for long-term protection of human health and the environment. The site is designated for open space and recreational use. Community acceptance will be further evaluated following the public comment period.

5.1.2 Alternative 2A—Variable Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring

Alternative 2A consists of the following components:

- Land use and access restrictions
- Non-RCRA and RCRA multilayer cap (with surface drainage and erosion controls)
- Containment Barrier for groundwater control
- Gas venting and monitoring

5.1.2.1 Overall Protection of Human Health and the Environment

Alternative 2A is protective of human health and the environment. The combination of land use and access restrictions; the installation of the non-RCRA and RCRA multilayer cap; the Containment Barrier for groundwater control; and gas venting and monitoring will meet the RAOs. This alternative eliminates the exposure pathways of concern by isolating the contaminated materials and refuse under the cap, eliminating groundwater movement outside the containment area, and providing for gas venting and monitoring and protection of the cap.

5.1.2.2 Compliance with ARARs

Table 5-1 lists overall potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables. Select ARARs and compliance with these ARARs are discussed below. Alternative 2A will comply with all action and location-specific ARARs. Several action-specific landfill capping, closure, and monitoring requirements are applicable for this alternative. Prescriptive Federal regulations for capping and post-closure contained in Code of Federal

Regulations, Title 40 (40 CFR), Parts 258.60 and 258.61 and 40 CFR Part 265, as well as State regulations including California Code of Regulations Title 27 (27 CCR), Division 2, Sections 21090 and 20950, are applicable and will be complied with during the final design of the proposed cap and in the course of post-closure O&M activities. The multilayer soil cap design will meet the requirements of a prescriptive cap as described in 27 CCR, Division 2, Section 21140 and Title 22 CCR, Section 66265 for the interim status regulated facilities.

In addition, groundwater monitoring requirements in 27 CCR, Division 2, Section 20390, as well as Federal regulation 40 CFR Part 258.61, are applicable and are complied with using the proposed groundwater monitoring program for this alternative. A groundwater monitoring plan is in place and will be modified for use when the remedial action is complete to meet RCRA interim status closure requirements as well as Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements.

Substantive requirements in the Bay Area Air Quality Management District Regulation 6 are considered applicable to this alternative. Specifically, Regulations 6-301, 6-302, and 6-305 that contain particulates and visible emissions standards will be applicable to limit dust and particulate emissions during excavation and stockpiling of cover material. Dust control will likely include water, spraying and/or proper covering of stockpiled soils, and other acceptable engineering means.

Extracted groundwater will be discharged to the Vallejo Sanitation and Flood Control District (VSFCD); the discharge to this publicly owned treatment works (POTW) will be covered under 40 CFR 403.5 and local discharge limits. The extracted groundwater will continue to be tested to ensure it meets discharge limits, and if needed, will be pre-treated before discharge.

Federal and State rules regarding endangered species must be met because the salt marsh harvest mouse, an endangered species, is found in the Containment Area. Isolated wetlands, including Wetland X, will be capped. This action will eliminate the wetlands and adversely affect potential habitat for the salt marsh harvest mouse. Consultation with the appropriate agencies is in progress and a procedure for avoiding impacting the salt marsh harvest mouse has been developed regarding passive relocation or trapping by a permitted expert to avoid any impact on the salt marsh harvest mouse. These procedures are described in the wetlands mitigation plan

(LSA, 2005b). The plan also describes how the amount of valuable salt marsh harvest mouse and open water habitat will be created as mitigation for the loss of wetlands within the Containment Area. In addition, the 8.2 acres of created wetlands will connect previously isolated wetlands leading to a more robust system to address the "no net loss" of wetlands in accordance with the Clean Water Act.

5.1.2.3 Long-Term Effectiveness

This alternative is effective for long-term protection of human health and the environment. Refuse will be isolated from human and environmental receptors through capping and land use and access restrictions. Reducing the amount of infiltration through the cap will minimize generation of contaminated groundwater or leachate, and the Containment Barrier, which prevents contamination from moving off-site, will protect off-site groundwater.

Continual long-term effectiveness largely depends on proper cap maintenance. Grading and revegetation technologies are effective in reducing maintenance requirements because they minimize erosion, promote positive drainage, and control the flow of surface water. Planting with native species suited for the site will provide natural ongoing vegetative growth with minimal maintenance. Once a native plant community is established, long-term maintenance is extremely low because weeds and/or non-native species are minimized. Ongoing maintenance may be required to control possible surface erosion and effects of differential settlement.

Long-term effectiveness and permanence of the RCRA and non-RCRA multilayer caps will also be affected by potential settlement of the underlying refuse and Bay Mud layers under the weight of the proposed cap. Geotechnical studies have been completed for the RCRA/Facility landfill. Settlement of landfill refuse and engineering control measures will be evaluated during the design phase and the cap will be designed to maintain long-term integrity and to withstand the maximum credible earthquake. Appropriate surface water runoff design will be incorporated into the final cap design.

The DON and WESTON, through the Environmental Services Cooperative Agreement (ESCA) agreement are responsible for providing long-term maintenance of the remedy in perpetuity if necessary. The requirements for the interim status RCRA Landfill requires at least a 30-year

maintenance period. The design of the cap, the native vegetative cover, and the long-term implementation of the O&M plan ensures that the cap provides adequate protection to human health and the environment over the long term.

As shown in Figure 4-1, the cap will cover Wetland X and other small, unnamed wetland areas. The affected wetland area consists of 2.0 acres of contaminant-impacted pickleweed, 0.5 acres of seasonally ponded areas, and 4.7 acres of low-value, disturbed seasonal wetlands. These wetlands are also isolated from the extensive pickleweed marsh wetlands to the west and south. Given this isolation and history of contamination, lack of tidal influence, and other factors, the wetlands to be impacted have limited functional value.

A total of 8.2 acres of new wetlands will be created, including 1.5 acres of ponded water wetlands and 6.7 acres of higher value pickleweed marsh in the Upland Areas of IA-H1, to offset the Wetland X loss. The proposed creation of wetlands from current Upland Areas will also connect existing isolated wetlands. The new wetlands will provide better functional habitat than the seasonal wetlands currently in the Containment Area. The new wetlands will provide three times the amount of salt marsh harvest mouse habitat (Pickleweed) and three times the amount of seasonally ponded water wetlands that will be lost in the remediation. The overall goal of wetland mitigation is to replace lost wetland functions and values, as well as to create functional habitat for a variety of wildlife species, including the salt marsh harvest mouse. The development of the new wetlands will take place concurrently with wetland impact activities. Monitoring to ensure the created wetlands develop appropriately is included in the wetland mitigation plan (LSA, 2005b). Once established, the wetland will provide ongoing benefits. Appropriate protective measures will be implemented to minimize impacts on endangered species during construction of the cap in the wetlands. These include appropriate trapping methods or passive relocation of salt marsh harvest mice. Vegetation will be removed immediately after the final trapping interval to ensure the mice do not return to the area. The created wetlands will provide long-term equal or better value wetlands to the area.

5.1.2.4 Reduction of Toxicity, Mobility, or Volume

Installation of the cap will reduce the potential for rainwater to infiltrate the refuse and produce additional leachate. The installed Containment Barrier and groundwater extraction trench will

virtually eliminate lateral movement of contaminated groundwater from the Containment Area. Natural attenuation is the only process providing for reduction of toxicity in this alternative.

5.1.2.5 Short-Term Effectiveness

Capping is a standard engineering process and standard safety precautions will be undertaken to reduce the likelihood of accidents during construction. This alternative poses minimal risk to the community during implementation. This alternative does not expose the existing waste during implementation, and off-site truck traffic is limited to delivery of materials. Residences are located 2500 feet from IAH1. No impacts on residences are expected from construction activities. Some exposure to dust from foundation or cover soil grading or placement generated by construction equipment is possible but unlikely given the distance of residences from the site. Measures, such as water suppression, will be taken to reduce and control short-term risks, such as inhalation and direct contact with fugitive dust. The extent and quantity of fugitive dust generation will be measured using real-time particulate monitors to verify that these measures are effective. Site access will be controlled during construction to reduce the potential for direct contact of unauthorized persons with fugitive dust.

This alternative poses minimal risk to workers during implementation since minimal intrusive work is required. Work would be carried out under an approved Occupational Safety and Health Administration (OSHA)-compliant Health and Safety Plan (HASP) to protect workers. Worker safety considerations associated with implementing this alternative include general site hazards and potential chemical hazards. General site hazards, such as heavy equipment and occupational noise, may be reduced through safety training and by providing safety equipment. Potential chemical hazards include inhalation of, direct contact with, absorption of, and ingestion of hazardous substances in contaminated soil. Personal protective equipment (PPE), including proper respiratory protection and protective clothing as appropriate, will be used to minimize the potential for workers to be exposed to hazardous materials. Air monitoring will be conducted to select the required level of protection. Vehicle decontamination stations will be provided to reduce dispersal of contamination outside the contamination reduction zone.

Truck traffic during cap construction may temporarily (approximately 3 to 6 months) increase noise and dust. Surface water runoff controls will be put in place during construction, and with

construction performed mostly in the non-rainy season, they should have a minimal impact. There are no known archaeological or cultural resources present in the project area and the remedy will not have disproportionate negative effects on minority and/or low-income populations.

5.1.2.6 Implementability

Alternative 2A is expected to be technically and administratively implementable. The Containment Barrier and groundwater extraction trench were completed in September 2004. Most equipment used for implementing the capping portion of the remedy consists of standard road construction equipment. Additional soil and base material will be required and may be obtained on or off site. There are adequate numbers of local construction and trained personnel to complete the task in approximately 6 months. The two capping designs will work well together and the transition from one cap to another will not cause any construction problems, as the transition will be to continue the same type of liner without the GCL layer.

5.1.2.7 Cost

The capital cost for Alternative 2A is $21,844,000. Most of the cost is associated with material purchases for the cap and grading, hauling, and placement of cap materials. Annual O&M costs for this alternative include groundwater collection, cap maintenance, and gas monitoring. O&M costs are estimated at a net present value of $7,066,000. The total cost for this alternative (including capital and O&M costs and a 25 percent contingency factor) is $28,910,000. In addition, the vertical Containment Barrier that has already been installed cost $2,390,000, bringing the overall total cost to $31,300,000. The cost estimate for this alternative is shown in Table 5-2.

5.1.2.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.1.2.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.1.3 Alternative 2B—RCRA Multilayer Cap, Institutional Controls, Groundwater Containment, and Gas Monitoring

Alternative 2B is similar to Alternative 2A except that it applies the RCRA cap (which includes the geosynthetic membrane liner [GCL]) over the entire Containment Area, affecting cost. Alternative 2B is slightly more difficult to implement because more care is required when installing the GCL. The GCL surface area coverage is the main difference between the two caps. The main contaminants outside the RCRA/Facility Landfill (weathered oil and metals) with intermittent other inert debris materials, are readily contained by either Alternative 2A or 2B, although Alternative 2B provides an additional measure of conservation since the GCL provides leak protection for the cover if the overlaying geomembrane is damaged.

Costs are increased in this alternative over Alternative 2A by $2,700,000. The capital cost for Alternative 2B is $24,544,000. Most of the additional cost is associated with material purchases for the purchase and placement of the GCL. O&M costs for this alternative include groundwater collection, cap maintenance, and gas monitoring. The net present value O&M cost is estimated at $7,066,000. The total cost for this alternative (including capital and O&M costs and a 25 percent contingency factor) is $31,610,000 In addition, the vertical Containment Barrier that has already been installed cost $2,390,000, bringing the overall total cost to $34,000,000. The cost estimate for this alternative is shown in Table 5-3.

5.1.4 Alternative 3—Removal and Disposal

Alternative 3 consists of the following components:

- Mechanical excavation of contaminated soil, replacement with clean backfill to a sufficient grade, and surface restoration
- Off-site disposal of contaminated soil and landfill refuse
- Engineering control measures to prevent airborne dust emissions from the site and to control surface erosion
- Safety procedures for handling potential munitions and explosives of concern (MEC) and radiological material

5.1.4.1 Overall Protection of Human Health and the Environment

Removal and disposal of material in another landfill will simply move contamination from one area to another. Short-term risks will be significantly higher than those of Alternatives 2A and 2B due to the intensity of removal activities and amount of material that must be excavated, handled, and transported on public roads to off-site disposal facilities. Excavation of the heterogeneous landfill material and exposing potentially hazardous materials will increase hazards to on-site workers. Total removal may provide long-term protection of on-site human health and the environment; however, there will still be a potential for residual contamination left in underling soils once all refuse is removed. In addition, the contaminated material will still exist, it will be simply placed in a different location that will have enhanced containment.

5.1.4.2 Compliance with ARARs

Table 5-1 list overall potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables. The excavation and disposal of the landfill materials will trigger a variety of hazardous waste requirements under the California Hazardous Waste Control Law. Some material excavated from the landfill may be hazardous waste that is managed, stored, and transported in accordance with the substantive Federal requirements in CFR Title 49, Part 171, as well as the State of California requirements in 22 CCR, Sections 66262.2 through 66262.23 and 66262.30 through 66262.34.

As appropriate, excavated material will be handled and treated to comply with disposal restrictions of 22 CCR, Section 66268.7. In addition, if the soil is not hazardous waste, it will be characterized according to CCR Title 27 requirements for solid and designated waste to determine whether the material may be disposed of at a permitted Class II or Class III landfill.

5.1.4.3 Long-Term Effectiveness

Removal and disposal of material in another landfill will simply move contamination from one area to another. Total removal may provide protection of human health and the environment at

IA-H1. There will still be a potential for residual contamination left in underling soils once all refuse is removed; the contaminated material will still exist in a different location.

5.1.4.4 Reduction of Toxicity, Mobility, or Volume

Removal will transfer the toxicity and volume of the Containment Area to another site. Once removed, the refuse and contaminated material will not pose a mobility issue at IA-H1. Approximately 950,000 cubic yards of material will be moved to anther location.

5.1.4.5 Short-Term Effectiveness

Short-term risks will be high due to the intensity of removal activities, amount of material that must be excavated, handled, and transported on public roads to off-site disposal facilities, and potential MEC issues. Excavation of the heterogeneous landfill material and exposing potentially hazardous materials will increase hazards to on-site workers. This option will impact existing wetlands. Wetland mitigation measures described for Alternative 2A would also need to be implemented for this alternative.

This alternative will take 2 years or more and require up to 50,000 truck trips to complete. In addition to the off-site landfill capacity issues, many current landfills that could accept this material are in economically disadvantaged areas.

5.1.4.6 Implementability

The implementability of this option is questionable. The equipment needed to remove the approximately 950,000 cubic yards of material in a reasonable timeframe, capacity in other landfills, and the amount of clean fill required to re-grade after the removal, may be difficult to obtain. In addition, this remedy essentially only moves contamination from one site to another.

5.1.4.7 Cost

The cost for Alternative 3 is $218,201,000 including a 25 percent contingency factor. Most of the cost is associated with disposal, excavation, and clean fill. No annual O&M costs for this option

are included, as total removal of the landfill may qualify for a clean closure. The cost estimate for this alternative is shown in Table 5-4.

5.1.4.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.1.4.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.2 UPLAND AREAS OUTSIDE THE CONTAINMENT BARRIER

5.2.1 Alternative 1—No Action

Under this alternative, no action is taken to alter the Upland Areas.

5.2.1.1 Overall Protection of Human Health and the Environment

The "No Action" alternative will not provide overall protection of human health and the environment because no long-term erosion, reduction, removal, or containment measures are implemented to protect human and ecological receptors. Direct contact with contaminated materials for a child recreational user and ecological receptors will not be eliminated under this alternative. The "No Action" alternative does not effectively reduce the long-term risk potential posed at the site.

5.2.1.2 Compliance with ARARs

Several location-specific ARARs may not be met under the "No Action" alternative. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.2.1.3 Long-Term Effectiveness

The "No Action" alternative will not provide long-term protection because no long-term erosion, contaminant reduction, removal or containment measures are implemented to protect human and ecological receptors. Direct contact with contaminated materials for a child recreational user and ecological receptors will not be reduced or eliminated under this alternative.

5.2.1.4 Reduction of Toxicity, Mobility, or Volume

The "No Action" alternative will not result in a reduction in toxicity, mobility, or volume, except for that resulting from natural attenuation processes. The risk would remain the same as the risk posed today and shown in the original baseline risk assessments described in Section 2.

5.2.1.5 Short-Term Effectiveness

This alternative will not have any short-term impacts, as it does not involve remediation activities.

5.2.1.6 Implementability

This alternative is readily implementable.

5.2.1.7 Cost

There are no direct costs associated with this remedy.

5.2.1.8 State Acceptance

The "No Action" alternative may not be acceptable by the State because it does not provide long-term protection of human health and the environment. State acceptance will be further evaluated following the public comment period.

5.2.1.9 Community Acceptance

The public may not find this alternative acceptable because it does not provide for long-term protection of human health and the environment. The site is designated for open space and recreational uses. Community acceptance will be further evaluated following the public comment period.

5.2.2 Alternative 2–Institutional Controls, Hot Spot Removal (Hazard Quotient [HQ] = 10), Groundwater Monitoring, and 2-Foot Soil Cover

Upland Areas Alternative 2 involves the following components:

- Institutional controls
- Hot spot removal including soils with an ecological HQ of 10 and threats to groundwater and human health
- 2-foot soil cover
- Groundwater monitoring

Under this alternative, hot spots identified in Section 3, will be removed, contaminated soil consolidated within in the Containment Area, and a 2-foot soil cover installed over the Upland Areas. The Green Sands Area will also be excavated as a hotspot. An estimated 46,843 cubic yards of impacted soil will be removed and consolidated. Groundwater monitoring will be conducted in the shallow water-bearing zone (SWBZ) to detect any potential movement of contaminants to the Non-Tidal Wetland Areas.

5.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 will reduce exposure to chemicals of concern (COCs) by human receptors through land and groundwater use restrictions and elimination of hot spot areas within the Upland Areas for an HQ of 10. A 2-foot soil cover over the remaining soil will provide an adequate base for vegetative growth, which will have the added benefit of reducing particulate transport to the low-lying wetland areas of IA-H1 and cover the asbestos materials. The 2-foot soil cover will provide a barrier for any MEC materials or radiological items (if present). The 2-foot cover will also provide a barrier to exclude current ecological receptors from any remaining contamination.

Hot spot and green sand excavation will reduce exposure to subsurface soils in the event of future earthmoving activities at the site and prevent migration of chemicals in soil to the underlying groundwater. Hot spot excavation will also remove soil exhibiting the presence of oil or free product, thereby reducing the potential migration of free product to the groundwater.

Groundwater monitoring will detect any potential problems of contamination moving from the Upland Areas into the Non-Tidal Wetland Areas or confirm that there is no significant transfer.

5.2.2.2 Compliance with ARARs

Alternative 2 will meet the potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables. Under this alternative, the materials at concentrations above the hot spot screening criteria will be removed.

5.2.2.3 Long-Term Effectiveness

Alternative 2 provides long-term effectiveness as it includes the removal of soil to ensure that soils left on the site represent a cancer risk on the order of 10^{-5} ; note that ambient/background arsenic levels are greater than 1x 10^{-5} a non-hazard quotient of less than 1 for humans, and an ecological HQ less than 10 for ecological receptors. Residual risk for long-term effectiveness is based on the most likely and potentially exposed receptors of a child recreational user and a construction worker.

The total future reasonable maximum exposure (RME) lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., soil and groundwater) after removal of hot spots for Alternative 2 is 4.8×10^{-5}. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants within the 0 to 10 feet below ground surface (bgs) zone is 4.6×10^{-5} after hot spot removal but before installation of the 2-foot cover. The estimated cumulative hazard index (HI) is equal to 0.31 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure only is equal to 0.22. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than 1×10^{-5} is arsenic. The calculated exposure point concentration (EPC) for arsenic is 13.6

milligrams per kilogram (mg/kg), which is a significantly lower concentration than the 95th percentile ambient/background concentration of 36 mg/kg. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate for the remaining contaminants after hot spot removal is 6.9×10^{-6} before the addition of the 2-foot soil cover.

The total future RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., soil and groundwater) after removal of hot spots for Alternative 2 is 8.1×10^{-6}. The estimated cumulative HI is equal to 1.4 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure only is equal to 1.1. No individual chemical or target organ HI exceeded 1. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants after hot spot removal within the 0 to 10 feet bgs zone is 7.6×10^{-6} before the installation of the 2-foot soil cover. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate from soil for the remaining contaminants is 1.1×10^{-6}. Appendix C discusses the residual risk calculations in more detail.

5.2.2.4 Reduction of Toxicity, Mobility, or Volume

Soil excavated from the Upland Areas will be disposed of on site within the IA-H1 Containment Area. Treatment alternatives were not considered since the material will be consolidated with other on-site contaminated material and capped within the Containment Area. In addition, the material contains a heterogeneous mixture of concrete, wire, and other debris that would interfere with soil processing systems. Soil excavation will not permanently reduce the toxicity or volume of the contamination but will transfer the contaminated soil to the Containment Area where the containment remedy will prevent migration of soil contaminants and leaching of any contaminants to uncontained groundwater.

A 2-foot soil cover will provide a significant reduction in mobility from the Upland Areas to Non-Tidal Wetland Areas by providing a barrier for erosion control and supporting vegetative growth, which will further stabilize the cover.

5.2.2.5 Short-Term Effectiveness

Removal operations are standard engineering processes and standard safety precautions will be undertaken to reduce the likelihood of accidents during construction. Alternative 2 poses minimal risk to the community during implementation. Residences are located approximately 2,500 linear feet from IA-H1, but not upwind of the site based on prevailing wind direction. Some exposure to dust raised by construction equipment is possible but is unlikely given the distance and direction of residences from the site. Measures will be taken to reduce and control short-term risks, such as inhalation of and direct contact with fugitive dusts. The extent and quantity of fugitive dust generation will be monitored to check that these measures are effective. Site access will be controlled during construction to reduce the potential for unauthorized persons to come into direct contact with contaminants.

Work will be carried out under an approved OSHA-compliant HASP to protect workers. Worker safety considerations associated with implementing this alternative include general site hazards and potential chemical hazards. General site hazards, such as heavy equipment and occupational noise, can be reduced through safety training and by providing safety equipment. Potential chemical hazards include inhalation of, direct contact with, absorption of, and ingestion of hazardous substances in contaminated soil. PPE, including proper respiratory protection and protective clothing, will be used to minimize the potential for workers to be exposed to hazardous materials. Air monitoring will be conducted to select the required level of protection. Vehicle decontamination stations will be provided to reduce dispersal of contamination outside the contamination reduction zone.

Surface water runoff controls will be put in place during construction, and with construction performed mostly in the non-rainy season, should have a minimal impact. There are no known archaeological or cultural resources present in the project area, and the remedy would not have disproportionate negative effects on minority and/or low-income populations.

5.2.2.6 Implementability

The technologies (traditional earthmoving) associated with Alternative 2 are proven and are easy to implement. Excavation of soil to the required depths and soil transport are common and

readily implementable practices, and materials and equipment are readily available. Construction for the removal phase will take approximately 2 months.

5.2.2.7 Cost

The capital cost for Alternative 2 is $2,976,000 including a 25 percent contingency factor. Most of the cost is associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. The cost estimate for this alternative is shown in Table 5-5.

5.2.2.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.2.2.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.2.3 Alternative 3—Institutional Controls, Hot Spot Removal (HQ=5), Groundwater Monitoring and 2-Foot Soil Cover

Upland Areas Alternative 3 involves the following components:

- Institutional Controls
- Hot spot removal including soils with an ecological HQ of 5 and threats to groundwater and human health
- Groundwater Monitoring
- 2-Foot Soil Cover

5.2.3.1 Overall Protection of Human Health and the Environment

Alternative 3 will reduce exposure to COCs by human receptors through land and groundwater use restrictions, placement of a soil cover, and elimination of hot spot areas presenting a threat to groundwater and an ecological HQ greater than 5 within the Upland Areas. The Green Sands Area will also be excavated as a hotspot. An estimated 47,087 cubic yards of impacted soil will be removed and consolidated within the Containment Area. The 2-foot soil cover will provide a

good base for vegetative cover and provide a barrier for any MEC materials, asbestos, or radiological items. The soil cover will also prevent particulate transport from contaminated surface soil to the low-lying Non-Tidal Wetland Areas of IA-H1.

The green sand and hot spot excavation will reduce exposure to subsurface soil in the event of future earthmoving activities at the site and prevent migration of chemicals in soil to the underlying groundwater. Hot spot excavation will also remove soil exhibiting the presence of oil or free product, thereby reducing the potential migration of free product to the groundwater. Soil above an ecological HQ of 5 will also be removed.

Groundwater monitoring will detect any potential problems of contamination moving from the Upland Areas into the Non-Tidal Wetland Areas or confirm that there is no significant transfer

5.2.3.2 Compliance with ARARs

Alternative 3 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.2.3.3 Long-Term Effectiveness

Alternative 3 will reduce the risk to human and ecological receptors from exposure to soil contaminants. This alternative includes excavation of hot spot areas within the Upland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a HI of less than 1 for noncancer adverse health effects, an ecological HQ of less than 5 (surface soil only), and removing threat to groundwater areas exhibiting visible oil or free product.

The total future RME lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., soil and groundwater) after removal of hot spots, but before the addition of the 2-foot soil cover, for Alternative 3 is $4.8x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants within the 0 to 10 feet bgs zone is $5.2x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 0.30 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure is equal to 0.21. No

individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than $1x10^{-5}$ is arsenic. The calculated EPC for arsenic is 13.6 mg/kg, which is a significantly lower concentration than the 95th percentile ambient/background concentration of 36 mg/kg. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate for the remaining contaminants is $5.1x10^{-6}$.

The total future RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., soil and groundwater) after removal of hot spots for Alternative 2 is$8.1x10^{-6}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants within the 0 to 10 feet bgs zone is $7.26x10^{-7}$ after hot spot removal but before the addition of the 2-foot soil cover. The estimated cumulative HI is equal to 1.4 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure is equal to 1.1. No individual chemical or target organ HI exceeded 1. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate for the remaining contaminants is $7.2x10^{-7}$. Appendix C discusses the residual risk calculations in more detail.

5.2.3.4 Reduction of Toxicity, Mobility, or Volume

See the discussion for Alternative 2, in Section 5.2.2.4.

5.2.3.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that there is more material that will be removed and, therefore, there is a slight increase for potential for worker exposure. Discussion of short-term effectiveness is provided in Section 5.2.2.5.

5.2.3.6 Implementability

Implementability of Alternative 2 and Alternative 3 are similar, with the exception that more material will require removal under Alternative 3. Section 5.2.2.6 provides a discussion on implementability. This alternative would require about 2 months to complete.

5.2.3.7 Cost

The capital cost for Alternative 3 is $3,006,000 including a 25 percent contingency factor. Most of the cost is associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. Annual O&M costs for this alternative include inspections to ensure institutional controls are working. The cost estimate for this alternative is shown in Table 5-6.

5.2.3.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.2.3.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.2.4 Alternative 4—Institutional Controls, Hot Spot Removal (HQ=3), Groundwater Monitoring, and 2-Foot Soil Cover

Upland Areas Alternative 4 involves the following components:

- Institutional Controls
- Hot spot removal including soils with an ecological HQ of 3 and threats to groundwater and human health
- Groundwater Monitoring
- 2-Foot Soil Cover

5.2.4.1 Overall Protection of Human Health and the Environment

Alternative 4 will reduce exposure to COCs by human receptors through land and groundwater use restrictions, placement of a soil cover, and elimination of hot spot areas presenting a threat to

groundwater and an ecological HQ greater than 3 within the Upland Areas. The Green Sands Area will also be excavated as a hot spot. An estimated 51,030 cubic yards of impacted soil will be removed and consolidated within the Containment Area. The 2-foot soil cover will provide a good base for vegetative cover and provide a barrier for any MEC materials, asbestos, or radiological items. The soil cover will also prevent particulate transport from contaminated surface soil to the low-lying wetland areas of IA-H1 and provide a barrier for ecological receptors.

The green sand and hot spot excavation will reduce exposure to subsurface soil in the event of future earthmoving activities at the site and prevent migration of chemicals in soil to the underlying groundwater. Hot spot excavation will also remove soil exhibiting the presence of oil or free product, thereby reducing the potential migration of free product to the groundwater. Soil above an ecological HQ of 3 will also be removed. The 2-foot soil cover will also provide a barrier for ecological receptors.

Groundwater monitoring will detect any potential problems of contamination moving from the Upland Areas into the Non-Tidal Wetland Areas or confirm that there is no significant transfer

5.2.4.2 Compliance with ARARs

Alternative 4 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.2.4.3 Long-Term Effectiveness

Alternative 4 will reduce the risk to human and ecological receptors from exposure to soil contaminants. This alternative includes excavation of hot spots within the Upland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a H1 of less than 1 for noncancer adverse health effects, an ecological HQ of less than 3 (surface soil only), and removing threat to groundwater areas exhibiting visible oil or free product. The total future RME lifetime excess cancer risk estimate to a recreational user for all exposure media (i.e., soil and groundwater) after

removal of hot spots, but before the installation of the 2-foot soil cover, for Alternative 4 is 4.7×10^{-5}. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants within the 0 to 10 feet bgs zone, after the 2-foot soil cover is placed, is 5.1×10^{-5} after hot spot removal. The estimated cumulative HI is equal to 0.30 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure is equal to 0.21. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than 1×10^{-5} is arsenic. The calculated EPC for arsenic is 13.6 mg/kg, which is a significantly lower concentration than the 95th percentile ambient/background concentration of 36 mg/kg. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate for the remaining contaminants is 4.4×10^{-6}.

The total future RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., soil and groundwater) after removal of hot spots and before placement of the 2-foot soil cover for Alternative 4 is 7.9×10^{-6}. The total lifetime excess cancer risk estimate for exposure to the remaining soil contaminants within the 0 to 10 feet bgs zone is 7.2×10^{-6} after hot spot removal. The estimated cumulative HI is equal to 1.4 for combined soil and groundwater exposure. The estimated cumulative HI for soil exposure is equal to 1.1. No individual chemical or target organ HI exceeded 1. Exposure to arsenic accounts for 85 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for soil, the total risk estimate for the remaining contaminants is 7.0×10^{-7}.

5.2.4.4 Reduction of Toxicity, Mobility, or Volume

See discussion for Alternative 2 in Section 5.2.2.4.

5.2.4.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that there is more material that will be removed and, therefore, there is a slight increase for potential for worker exposure. Discussion of short-term effectiveness is provided in Section 5.2.2.5.

5.2.4.6 Implementability

Implementability of Alternative 2 and Alternative 4 are similar, with the exception that more material will require removal under Alternative 4. Section 5.2.2.6 provides a discussion on implementability. This alternative would take about 2 months to complete.

5.2.4.7 Cost

The capital cost for Alternative 4 is $3,160,000 including a 25 percent contingency factor. Most of the cost is associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. Annual O&M costs for this alternative include inspections to ensure institutional controls are working that would be done in conjunction with O&M for the Containment Area. The cost estimate for this alternative is shown in Table 5-7.

5.2.4.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.2.4.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.2.5 Alternative 5—Debris excavation and Groundwater Monitoring

Upland Areas Alternative 5 involves the following components:

- Excavation of all the debris areas in the Upland Areas
- Groundwater Monitoring

5.2.5.1 Overall Protection of Human Health and the Environment

Removal of debris in the Upland Areas will remove the hazards contained in that debris. The only exposure pathway would be any groundwater that may already be contaminated. Monitoring would be implemented to ensure that any contaminated groundwater does not pose a hazard.

5.2.5.2 Compliance with ARARs

Alternative 5 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.2.5.3 Long-Term Effectiveness

The future exposure scenario evaluated soil at depths of 0 to 10 feet bgs within the Upland Areas of IA-H1. Alternative 5 includes excavation of all debris disposal areas across the majority of the Upland Areas with placement within the Containment Area. The debris excavation would capture most of the significant concentrations of all chemicals present within the Upland Areas of IA-H1. The human health and ecological risk associated with soil within the 0 to 10 feet bgs range would essentially be eliminated. Complete removal of debris is permanent and effective.

5.2.5.4 Reduction of Toxicity, Mobility, or Volume

No reduction in toxicity or volume would be achieved; however, the mobility of the contaminants placed in the Containment Area would be eliminated.

5.2.5.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that there is much more material will be removed and, therefore, there is an increase for potential for worker exposure. Discussion of short-term effectiveness is provided in Section 5.2.2.5. This alternative would take 12 to 18 months to complete.

5.2.5.6 Implementability

Implementability of Alternative 5 is possible but this alternative would require moving approximately 453,850 cubic yards of material. This is an order of magnitude greater than the other alternatives leading to a much longer time to completion and greater construction effort. The methods for moving material are similar to those described in Section 5.2.2.6. This would

also significantly increase the loading within the Containment Area, which will complicate the cover design relative to settlement issues.

5.2.5.7 Cost

The capital cost for Alternative 5 is $19,181,000 including a 25 percent contingency factor. Most of the cost is associated with equipment, grading, hauling, and confirmation sampling. Annual O&M costs for this alternative include inspections to ensure institutional controls are working that would be done in conjunction with O&M for the Containment Area. The cost estimate for this alternative is shown in Table 5-8.

5.2.5.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.2.5.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.3 NON-TIDAL WETLAND AREAS OUTSIDE THE CONTAINMENT BARRIER

5.3.1 Alternative 1—No Action

Under this alternative, no action is taken to alter the Non-Tidal Wetland Areas.

5.3.1.1 Overall Protection of Human Health and the Environment

Since the "No Action" alternative does not contain any remedial activities, there is no reduction of present and future risks associated with this alternative. No protection of human health and the environment is afforded.

5.3.1.2 Compliance with ARARs

The "No Action" alternative will not comply with all of the action-specific ARARs relative to groundwater and closure of landfills. Several location-specific ARARs may not be met under the

"No Action" alternative. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.3.1.3 Long-Term Effectiveness

The "No Action" alternative does not reduce the toxicity, mobility, or volume of the site contaminants through treatment because no remedial action is implemented.

5.3.1.4 Reduction of Toxicity, Mobility, or Volume

There is no reduction of present and future risks associated with the "No Action" alternative. No additional protection of human health and the environment is afforded.

5.3.1.5 Short-Term Effectiveness

The "No Action" alternative will not have any short-term impacts, as it does not involve remediation activities.

5.3.1.6 Implementability

The "No Action" alternative is easily implemented.

5.3.1.7 Cost

There are no direct costs associated with the "No Action" alternative.

5.3.1.8 State Acceptance

State acceptance of the "No Action" alternative is uncertain as this alternative provides no protection of human health and the environment. State acceptance will be further evaluated following the public comment period.

5.3.1.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.3.2 Alternative 2—Institutional Controls, Hot Spot Removal (HQ=10), and Monitoring

Non-Tidal Wetland Areas Alternative 2 involves the following components:

- Institutional controls
- Hot spot removal based on human health risk and ecological risk for the high TRV HQ of 10
- Monitoring

Under this alternative, hot spots identified in Section 3, will be removed and disposed of in the Containment Area.

5.3.2.1 Overall Protection of Human Health and the Environment

Alternative 2 is protective of human health and the environment. This alternative will reduce exposure to COCs by human receptors through land use, access, and groundwater use restrictions and hot spot excavation. The institutional controls and access restrictions will reduce risk from surface water COCs. Hot spot excavation will reduce exposure to chemical concentrations in sediment presenting unacceptable risk levels to human and ecological receptors. All of the proposed hot spot excavation areas are small areas near the edges of the wetlands or in areas without pickleweed vegetation. Mitigation measures to protect the salt marsh harvest mouse will be implemented during work in these areas as described in the Biological Assessment (LSA, 2005a). This alternative will meet the RAOS.

5.3.2.2 Compliance with ARARs

Alternative 2 will meet the requirements of the identified potential ARARs except that the Salt Marsh Harvest Mouse may require additional action. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.3.2.3 Long-Term Effectiveness

Alternative 2 will reduce the risk to human and ecological receptors from exposure to sediment contaminants by removing hot spots of contamination. This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a H1 of less than 1 for noncancer adverse health effects, an ecological HQ of less than 10 (surface oil only), and removing threat to groundwater areas exhibiting visible oil or free product.

5.3.2.3.1 Human Health Risk

The total RME lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., sediment, soil, groundwater, and surface water) after removal of hot spots for Alternative 2 is $8.4x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $6.4x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 0.33 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 0.22. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than $1x10^{-5}$ is arsenic. The calculated EPC for arsenic is 21.5 mg/kg, which is a lower concentration than the ambient/background concentration of 36 mg/kg. The cancer risk estimate for exposure to arsenic is $6.1x10^{-5}$, which is lower than the ambient/background cancer risk estimate for arsenic. Exposure to arsenic accounts for 96 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for sediment, the total risk estimate for the remaining contaminants is $2.8x10^{-6}$.

The total RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., sediment, soil, and groundwater) after removal of hot spots for Alternative 2 is $1.1x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $1.1x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 1.5 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 1.2. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate

greater than $1x10^{-5}$ is arsenic. The calculated EPC for arsenic is 21.5 mg/kg, which is a lower concentration than the ambient/background concentration of 36 mg/kg. The cancer risk estimate for exposure to arsenic is $1x10^{-5}$, which is lower than the ambient/background cancer risk estimate for arsenic. When exposure to arsenic is excluded from the total risk estimate for sediment, the total risk estimate for the remaining contaminants is $4.7x10^{-7}$.

5.3.2.3.2 Ecological Risk

Selenium in sediment presents a potential risk to the gray fox based on the low TRV. Lead in sediment presents a potential risk to the northern harrier and mallard (non-breeding) based on the low TRV. Copper, lead, and manganese in sediment present a potential risk to the mallard (breeding) based on the low TRV. Lead, selenium, and PCBs in sediment present a potential risk to the great blue heron based on the low TRV. No chemicals in sediment present a significant or immediate risk (HQ greater than 1 based on the high TRV) to the gray fox, northern harrier, mallard, or the great blue heron. There is a potential risk to the killdeer exposed to barium, cadmium, copper, lead, manganese, mercury, nickel, zinc, benzo(a)pyrene, and PCBs in sediment and a significant or immediate risk to the killdeer exposed to chromium in sediment. There is an immediate or significant risk (HQ greater than 1 based on the low TRV) to the salt marsh harvest mouse exposed to antimony, arsenic, cadmium, copper, lead, manganese, nickel, vanadium, and zinc in sediment.

While antimony, arsenic, barium, cadmium, manganese, mercury, nickel, and vanadium in sediment in the Non-Tidal Wetland Areas pose an ecological risk, these contaminants are present at ambient/background levels.

Monitoring to ensure disturbed areas are re-established as equivalent or better non-tidal wetlands will be included in the wetland mitigation plan. Once established, the wetland will provide ongoing benefits. Appropriate mitigation measures will be implemented to avoid impacts on the salt marsh harvest mouse during construction outlined in the Biological Assessment (LSA, 2005a).

5.3.2.4 Reduction of Toxicity, Mobility, or Volume

Sediment excavated from the Non-Tidal Wetland Areas will be disposed of on site within the Containment Area. Sediment excavation will not permanently reduce the toxicity or volume of the contamination but will transfer the contaminated sediment to a different area. Placement of the contaminated sediment inside the Containment Barrier will prevent lateral migration of soil contaminants and direct exposure when the cap is completed.

5.3.2.5 Short-Term Effectiveness

Removal operations are standard heavy earth-moving processes and standard safety precautions will be undertaken to reduce the likelihood of accidents during construction. Alternative 2 poses minimal risk to the community during implementation. Residences are located approximately 2,500 linear feet from IA-H1, but not upwind based on prevailing wind direction. Some exposure to dust raised by construction equipment is possible but is unlikely given the distance and direction of residences from the site. Measures will be taken to reduce and control short-term risks, such as inhalation of and direct contact with fugitive dusts. The extent and quantity of fugitive dust generation will be monitored to check that these measures are effective. Site access will be controlled during construction to reduce the potential for unauthorized persons to come into direct contact with contaminants.

Work will be carried out under an approved OSHA-compliant HASP to protect workers. Worker safety considerations associated with implementing this alternative include general site hazards and potential chemical hazards. General site hazards, such as heavy equipment and occupational noise, can be reduced through safety training and by providing safety equipment. Potential chemical hazards include inhalation of, direct contact with, absorption of, and ingestion of hazardous substances in contaminated soil. PPE, including proper respiratory protection and protective clothing, will be used to minimize the potential for workers to be exposed to hazardous materials. Air monitoring will be conducted to select the required level of protection. Vehicle decontamination stations will be provided to reduce dispersal of contamination outside the contamination reduction zone.

Surface water runoff controls will be put in place during construction, and with construction performed mostly in the non-rainy season, should have a minimal impact. There are no known archaeological or cultural resources present in the project area, and the remedy would not have disproportionate negative effects on minority and/or low-income populations

Wetland protections will be put in place during construction to have the minimum potential effect on the wetlands. Mitigative measures as described in the Biological Assessment (LSA, 2005a) will be implemented to protect the salt marsh harvest mouse. Any disturbed wetland area will be restored according to the Wetland Mitigation Plan (LSA, 2005b).

5.3.2.6 Implementability

The technologies (traditional earthmoving) associated with Alternative 2 are proven, well known, and are easy to implement. Excavation of soil to the required depths and soil transport are common and readily implementable practices, and materials and equipment are readily available. The time to implement this option is approximately 1 to 2 weeks.

Re-establishment of the small areas of wetland to equivalent or better value wetlands is achievable. The removal of contaminants and replacement with appropriate material should assist in the development. Appropriate fill and wetland plants and seeds are available from nurseries and from collected seeds. The amount of material to be removed under this alternative is 1,495 cubic yards.

5.3.2.7 Cost

The cost for Alternative 2 is $104,000. Most of the costs are associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. The cost estimate for this alternative is shown in Table 5-9.

5.3.2.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.3.2.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.3.3 Alternative 3—Institutional Controls, Hot Spot Removal (HQ=5), and Monitoring

Non-Tidal Wetland Areas Alternative 3 involves the following components:

- Institutional controls
- Hot spot removal based on human health risk and ecological risk for the high TRV HQ of 5
- Monitoring

Under this alternative, hot spots identified in Section 3 will be removed and disposed of in the Containment Area.

5.3.3.1 Overall Protection of Human Health and the Environment

Alternative 3 is protective of human health and the environment. This alternative will reduce exposure to COCs by human receptors through land use, access, and groundwater use restrictions and hot spot excavation. The institutional controls and access restrictions will reduce risk from surface water COCs. Hot spot excavation will reduce exposure to chemical concentrations in sediment presenting unacceptable risk levels to human and ecological receptors. All of the proposed hot spot excavation areas are small areas near the edges of the wetlands or in areas without pickleweed vegetation. Mitigation measures to protect the salt marsh harvest mouse will be implemented during work in these areas as described in the Biological Assessment (LSA, 2005a). This alternative will meet the RAOs.

5.3.3.2 Compliance with ARARs

Alternative 3 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.3.3.3 Long-Term Effectiveness

Alternative 3 will reduce the risk to human and ecological receptors from exposure to sediment contaminations by removing hot spots of contamination. This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a H1 of less than 1 for noncancer adverse health effects, an ecological HQ of less than 5 (surface soil only), and removing threat to groundwater areas exhibiting visible oil or free product.

5.3.3.3.1 Human Health Risk

The total RME lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., sediment, soil, groundwater, and surface water) after removal of hot spots for Alternative 3 is $8.2x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $6.3x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 0.32 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 0.22. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than $1x10^{-5}$ is arsenic. The calculated EPC for arsenic is 21 mg/kg, which is a lower concentration than the ambient/background concentration of 36 mg/kg. The cancer risk estimate for exposure to arsenic is $6.0x10^{-5}$, which is lower than the ambient/background cancer risk estimate for arsenic. Exposure to arsenic accounts for 95 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for sediment, the total risk estimate for the remaining contaminants is $2.9x10^{-6}$.

The total RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., sediment, soil, and groundwater) after removal of hot spots for Alternative 3 is $1.1x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $1.0x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 1.5 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 1.2. No individual chemical or target organ HI exceeded 1.

5.3.3.3.2 Ecological Risk

Selenium in sediment presents a potential risk to the gray fox based on the low TRV. Lead in sediment presents a potential risk to the northern harrier and mallard (non-breeding) based on the low TRV. Copper, lead, and manganese in sediment present a potential risk to the mallard (breeding) based on the low TRV. Lead, selenium, and PCBs in sediment present a potential risk to the great blue heron based on the low TRV. No chemicals in sediment present a significant or immediate risk (HQ greater than 1 based on the high TRV) to the gray fox, northern harrier, mallard, or the great blue heron. There is a potential risk to the killdeer exposed to barium, cadmium, copper, lead, manganese, mercury, nickel, zinc, benzo(a)pyrene, and PCBs in sediment and a significant or immediate risk to the killdeer exposed to chromium in sediment. There is an immediate or significant risk (HQ greater than 1 based on the low TRV) to the salt marsh harvest mouse exposed to antimony, arsenic, cadmium, copper, lead, manganese, nickel, vanadium, and zinc in sediment.

While antimony, arsenic, barium, cadmium, manganese, mercury, nickel, and vanadium in sediment in the Non-Tidal Wetland Areas pose an ecological risk, these contaminants are present at ambient/background levels.

Monitoring to ensure disturbed areas are re-established as equivalent or better non-tidal wetlands will be included in the wetland mitigation plan. Once established, the wetland will provide ongoing benefits. Appropriate protective measures will be implemented to avoid impacts to the salt marsh harvest mouse during construction as outlined in the Biological Assessment (LSA, 2005a).

5.3.3.4 Reduction of Toxicity, Mobility, or Volume

Sediment excavated from the Non-Tidal Wetland Areas will be disposed of on site within the Containment Area. Sediment excavation will not permanently reduce the toxicity or volume of the contamination but will transfer the contaminated sediment to a different area. Placement of the contaminated sediment inside the Containment Barrier will prevent lateral migration of soil contaminants and direct exposure once the cap is completed.

5.3.3.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that there is more material will be removed and, therefore, there is a slight increase for potential for worker exposure and more areas will need to be restored. Discussion of short-term effectiveness is provided in Section 5.3.2.5.

5.3.3.6 Implementability

Implementability of Alternative 2 and Alternative 3 are similar, with the exception that more material will require removal under Alternative 3. Section 5.3.2.6 provides a discussion on implementability. A total of 2,100 cubic yards of material would be removed under this alternative.

5.3.3.7 Cost

The cost for Alternative 3 is $141,000. Most of the costs are associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. The cost estimate for this alternative is shown in Table 5-10.

5.3.3.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.3.3.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period

5.3.4 Alternative 4—Institutional Controls, Hot Spot Removal (HQ=3), and Monitoring

Non-Tidal Wetland Areas Alternative 4 involves the following components:

- Institutional controls
- Hot spot removal based on human health risk and ecological risk for high TRV HQ of 3
- Monitoring

Under this alternative, hot spots identified in Section 3, will be removed and disposed of in the Containment Area.

5.3.4.1 Overall Protection of Human Health and the Environment

Alternative 4 is protective of human health and the environment. This alternative will reduce exposure to COCs by human receptors through land use, access, and groundwater use restrictions and hot spot excavation. The institutional controls and access restrictions will reduce risk from surface water COCs. Hot spot excavation will reduce exposure to chemical concentrations in sediment presenting unacceptable risk levels to human and reduce the hazards to ecological receptors. All of the proposed hot spot excavation areas are small areas near the edges of the wetlands or in areas without pickleweed vegetation. Mitigation measures to protect the salt marsh harvest mouse will be implemented during work in the areas as described in the Biological Assessment (LSA, 2005a). This alternative will meet the RAOs.

5.3.4.2 Compliance with ARARs

Alternative 4 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.3.4.3 Long-Term Effectiveness

Alternative 4 will reduce the risk to human and ecological receptors from exposure to sediment contaminations by removing hot spots of contamination. This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a H1 of less than 1 for noncancer adverse health effects, an ecological HQ of less than 3 (surface soil only), and removing threat to groundwater areas exhibiting visible oil or free product.

5.3.4.3.1 Human Health Risk

The total RME lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., sediment, soil, groundwater, and surface water) after removal of hot spots for Alternative 4 is 8.3×10^{-5}. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is 6.4×10^{-5} after hot spot removal. The estimated cumulative HI is equal to 0.32 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 0.21. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than 1×10^{-5} is arsenic. The calculated EPC for arsenic is 21.3 mg/kg, which is a lower concentration than the ambient/background concentration of 36 mg/kg. The cancer risk estimate for exposure to arsenic is 6.1×10^{-5}, which is lower than the ambient/background cancer risk estimate for arsenic. Exposure to arsenic accounts for 95 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for sediment, the total risk estimate for the remaining contaminants is 2.8×10^{-6}.

The total RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., sediment, soil, and groundwater) after removal of hot spots for Alternative 4 is 1.1×10^{-5}. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is 1.0×10^{-5} after hot spot removal. The estimated cumulative HI is equal to 1.5 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 1.2. No individual chemical or target organ HI exceeded 1.

5.3.4.3.2 Ecological Risk

Selenium in sediment presents a potential risk to the gray fox based on the low TRV. Lead in sediment presents a potential risk to the northern harrier and mallard (non-breeding) based on the low TRV. Copper, lead, and manganese in sediment present a potential risk to the mallard (breeding) based on the low TRV. Lead, selenium, and PCBs in sediment present a potential risk to the great blue heron based on the low TRV. No chemicals in sediment present a significant or immediate risk (HQ greater than 1 based on the high TRV) to the gray fox, northern harrier,

mallard, or the great blue heron. There is a potential risk to the killdeer exposed to barium, cadmium, copper, lead, manganese, mercury, nickel, zinc, benzo(a)pyrene, and PCBs in sediment and a significant or immediate risk to the killdeer exposed to chromium in sediment. There is an immediate or significant risk (HQ greater than 1 based on the low TRV) to the salt marsh harvest mouse exposed to antimony, arsenic, cadmium, copper, lead, manganese, nickel, vanadium, and zinc in sediment.

While antimony, arsenic, barium, cadmium, manganese, mercury, nickel, and vanadium in sediment in the Non-Tidal Wetland Areas do pose an ecological risk, these contaminants are present at ambient/background levels.

Monitoring to ensure disturbed areas are re-established as equivalent or better non-tidal wetlands will be included in the wetland mitigation plan. Once established, the wetland will provide ongoing benefits. Appropriate protective measures will be implemented to avoid impacts to the salt marsh harvest mouse during construction as outlined in the Biological Assessment (LSA, 2005a).

5.3.4.4 Reduction of Toxicity, Mobility, or Volume

Sediment excavated from the Non-Tidal Wetland Areas will be disposed of on site within the Containment Area. Sediment excavation will not permanently reduce the toxicity or volume of the contamination but will transfer the contaminated sediment to a different area. Placement of the contaminated sediment inside the Containment Barrier will prevent lateral migration of soil contaminants and direct exposure once the cap is completed.

5.3.4.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that there is more material will be removed and, therefore, there is a slight increase for potential for worker exposure and more areas will need to be restored. Discussion of short-term effectiveness is provided in Section 5.3.2.5.

5.3.4.6 Implementability

Implementability of Alternative 2 and Alternative 4 are similar, with the exception that more material will require removal under Alternative 4. Section 5.2.2.6 provides a discussion on implementability. A total of 2,825 cubic yards of soil and sediment will be removed for Alternative 4.

5.3.4.7 Cost

The cost for Alternative 4 is $181,000. Most of the costs are associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. The cost estimate for this alternative is shown in Table 5-11.

5.3.4.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.3.4.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

5.3.5 Alternative 5—Institutional Controls, Hot Spot Removal (HQ=1), and Monitoring

Non-Tidal Wetland Areas Alternative 5 involves the following components:

- Institutional controls
- Hot spot removal based on human health risk and ecological risk for high TRV HQ of 1
- Monitoring

Under this alternative, hot spots identified in Section 3, will be removed and disposed of in the Containment Area.

5.3.5.1 Overall Protection of Human Health and the Environment

Alternative 5 is protective of human health and the environment. This alternative will reduce exposure to COCs by human receptors through land use, access, and groundwater use restrictions and hot spot excavation. The institutional controls and access restrictions will reduce risk from surface water COCs. Hot spot excavation will reduce exposure to chemical concentrations in sediment presenting unacceptable risk levels to human and ecological receptors. All of the proposed hot spot excavation areas are small areas near the edges of the wetlands or in areas without pickleweed vegetation. Mitigation measures to protect the salt marsh harvest mouse will be implemented during work in these areas as described in the Biological Assessment (LSA, 2005a). This alternative will meet the RAOs.

5.3.5.2 Compliance with ARARs

Alternative 5 will meet the requirements of the identified potential ARARs. Table 5-1 lists potential ARARs for the remedial alternatives and indicates whether implementation of the alternatives would meet those requirements. Appendix A discusses the ARARs in more detailed tables.

5.3.5.3 Long-Term Effectiveness

Alternative 5 will reduce the risk to human and ecological receptors from exposure to sediment contaminations by removing hot spots of contamination. This alternative includes excavation of hot spot areas within the Non-Tidal Wetland Areas to achieve a residual cancer risk of $1x10^{-5}$ or better, a H1 of less than 1 for noncancer adverse health effects, an ecological HQ of less than 1 (surface soil only), and removing threat to groundwater areas exhibiting visible oil or free product.

5.3.5.3.1 Human Health Risk

The total RME lifetime excess cancer risk estimate to a child recreational user for all exposure media (i.e., sediment, soil, groundwater, and surface water) after removal of hot spots for Alternative 5 is $8.3x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $6.3x10^{-5}$ after hot

spot removal. The estimated cumulative HI is equal to 0.31 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 0.21. No individual chemical or target organ HI exceeded 1. The only remaining chemical exhibiting a cancer risk estimate greater than $1x10^{-5}$ is arsenic. The calculated EPC for arsenic is 21.2 mg/kg, which is a lower concentration than the 95th percentile ambient / background concentration of 36 mg/kg. The cancer risk estimate for exposure to arsenic is $6.1x10^{-5}$, which is lower than the ambient/background cancer risk estimate for arsenic of $4.2x10^{-5}$ (based on the 95UCL average concentration). Exposure to arsenic accounts for 95 percent of the total cancer risk estimate for exposure to soil. When exposure to arsenic is excluded from the total risk estimate for sediment, the total risk estimate for the remaining contaminants is $2.8x10^{-6}$.

The total RME lifetime excess cancer risk estimate to a construction worker for all exposure media (i.e., sediment, soil, and groundwater) after removal of hot spots for Alternative 5 is $1.1x10^{-5}$. The total lifetime excess cancer risk estimate for exposure to the remaining soil and sediment contaminants within the 0 to 10 feet bgs zone is $1.0x10^{-5}$ after hot spot removal. The estimated cumulative HI is equal to 1.4 for combined sediment, groundwater, and surface water exposure. The estimated cumulative HI for soil exposure is equal to 1.2. No individual chemical or target organ HI exceeded 1.

5.3.5.3.2 Ecological Risk

Monitoring to ensure disturbed areas are re-established as equivalent or better non-tidal wetlands will be included in the wetland mitigation plan. Once established, the wetland will provide ongoing benefits. Appropriate protective measures will be implemented to avoid impacts to the salt marsh harvest mouse during construction as outlined in the Biological Assessment (LSA, 2005a).

5.3.5.4 Reduction of Toxicity, Mobility, or Volume

Sediment excavated from the Non-Tidal Wetland Areas will be disposed of on site within the Containment Area. Sediment excavation will not permanently reduce the toxicity or volume of the contamination but will transfer the contaminated sediment to a different area. Placement of

the contaminated sediment inside the Containment Barrier will prevent lateral migration of soil contaminants and direct exposure once the cap is completed.

5.3.5.5 Short-Term Effectiveness

Short-term effectiveness will be similar to the short-term effectiveness of Alternative 2 with the exception that more material will be removed, and therefore, there is a slight increase for potential for worker exposure and more areas will need to be restored. Discussion of short-term effectiveness is provided in Section 5.3.2.5.

5.3.5.6 Implementability

Implementability of Alternative 2 and Alternative 5 are similar, with the exception that more material will require removal under Alternative 5. Section 5.2.2.6 provides a discussion on implementability. A total of 5,180 cubic yards will be removed for Alternative 5.

5.3.5.7 Cost

The cost for Alternative 5 is $365,000. Most of the costs are associated with equipment, grading, hauling, confirmation sampling, and placement of the soil cover. The cost estimate for this alternative is shown in Table 5-13.

5.3.5.8 State Acceptance

State acceptance will be further evaluated following the public comment period.

5.3.5.9 Community Acceptance

Community acceptance will be further evaluated following the public comment period.

6. DETAILED ANALYSIS OF ALTERNATIVES

This section analyzes the advantages and disadvantages of each of the alternatives evaluated in Section 5. Identification of a preferred alternative will be made within the proposed plan to be developed following this Feasibility Study (FS).

For an alternative to be eligible for selection as a preferred alternative, it must meet two Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) recognized threshold criteria:

1. Overall protection of human health and the environment
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

After the comparison with threshold criteria, a comparative analysis of remedial alternatives is conducted based on five CERCLA recognized primary criteria that identify and weigh the major tradeoffs among alternatives. The last two criteria, the modifying criteria of state and community acceptance, will be addressed based on comments received from the community and the agencies on the future proposed plan.

The goal of this comparative analysis is to provide a sound basis for remedy selection that is consistent with the National Contingency Plan (NCP).

6.1 THRESHOLD CRITERIA

Alternative 1 – "No Action" alternatives for each area (Containment Area, Upland Areas, and Non-Tidal Wetland Areas) do not meet the threshold criteria of overall protection of human health and the environment and compliance with ARARs for the open space/recreational use scenario. The "No-Action" alternative will result in site conditions that are controlled only by current land use practices. Without additional controls, land use could change giving rise to unacceptable exposure of contaminants to human and ecological receptors.

Because Alternative 1 does not meet the threshold criteria, this alternative is not eligible for selection as it does not meet the Remedial Action Objectives (RAOs), and it is not included in

further discussion. According to the NCP, however, the "No-Action" alternative provides a basis for comparison against other alternatives as discussed in Section 6.4.

As described in Section 5, except for the "No Action" alternatives, each other alternative for the Containment Area, Upland Areas, and Non-Tidal Wetland Areas, meet the threshold criteria for protection of human and ecological health and are compliant with ARARs.

6.2 BALANCING CRITERIA

The five criteria used for comparative analysis of remedial alternatives are discussed in this section:

- Long-Term Effectiveness and Permanence
- Reduction in Toxicity, Mobility, and Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

6.2.1 Long-Term Effectiveness and Permanence

6.2.1.1 Containment Area Alternatives

Alternatives 2A and 2B (Resource Conservation and Recovery Act [RCRA] and non-RCRA Multilayer Caps, Institutional Controls, Groundwater Containment, Gas Venting and Monitoring) and Alternative 3 (Removal and off-site Disposal) provide long-term effectiveness and permanence for the Landfill; however, Alternatives 2A and 2B depend on long-term maintenance of the cap. Alternative 3 will depend on the long-term management of an off-site waste disposal facility. Alternative 2B provides slightly greater protection from groundwater infiltration compared with Alternative 2A, since the geosynthetic clay liner (GCL) would be extended under the geomembrane liner over the entire Containment Area, not just the required RCRA-regulated areas. However, according to EPA guidance, all liners leak to a small degree; a 1 millimeter (mm) infiltration across the liner would be about 0.145 gallons per minute (gpm) (200 gallons per day, or 3 gallons per acre per day) for the entire 72-acre Containment Area. A

GCL would presumably reduce this small leakage even further, but since the entire area is surrounded by the slurry wall/extraction trench, a very small incremental leakage rate for Alternative 2A versus Alternative 2B is negligible. Even without a cap, the combined flowrate from the extraction system averaged just over 5 gpm during the recent dry-season months.

Groundwater infiltration is related to landfill gas generation and migration of soil contaminants. Since there is little or no landfill gas generation occurring outside the RCRA-regulated units, and the groundwater is totally contained by the surrounding slurry wall and extraction trench, there is little difference between Alternatives 2A and 2B in terms of long-term effectiveness and permanence.

Operations and maintenance procedures will be developed for the site that will include inspection and procedures to ensure proper maintenance of the cap. The entire Containment Area will be fenced.

6.2.1.2 Upland Areas Alternatives

Alternatives 2, 3, 4 (Institutional Controls, Hot Spot Removal HQ = 10, 5, and 3 respectively, Groundwater Monitoring, and 2-Foot Cover), and Alternative 5 (Debris Excavation, and Disposal) all provide long-term effectiveness and permanence. r the child recreational user. Alternatives 2, 3, and 4 are roughly equivalent, as all are protective of human health and groundwater, but Alternative 5 provides slightly more effectiveness in reducing the overall risks. Additional reduction in the overall ecological hazard quotient (HQ) by Alternative 4 is realized compared with Alternatives 2 and 3. Each remedy meets the target of hazard index (HI) values of less than 1 for human non-cancer effects. Alternative 5 will provide for the removal of more contaminants to the Containment Area with a slight incremental additional lowering of the human health and ecological risks. For the underlying materials, however, the overall risk for Alternatives 2 through 4 will be lower due to the application of a high quality 2-foot soil cover (lower ambient/background risk). Arsenic (the overwhelming residual risk driver), for example, in the baseline risk assessment for recreational users yielded a cancer risk of 5.2×10^{-5}, and the post remedy risk of 4.4×10^{-6} including the high quality fill material for the 2-foot soil cover for the recreational user. This is an improvement on what could be expected from

ambient/background risk levels at the site. Table 6-1 shows the Human Health Risk Values for each alternative as a comparison. Ambient/background arsenic levels contribute most of the human health risk as can be seen by the lower cancer risk levels when calculated excluding the ambient/background arsenic contribution. Alternative 5would reduce all future risk by removing all debris; however, short term risk would be increased for the construction crews as they dig through the debris. The low levels of calculated human risk do not take into account the additional benefit of the 2-foot soil cover, so total overall risk will actually be lower. Risk in the 0 to 2 foot level was not calculated because clean off-site cover material will be used as the soil cover. All remedial alternatives are protective of groundwater.

Ecological risk is the main difference between the alternatives. The differences in soil removal are based on the ecological risks calculated at high Toxicity Reference Values (TRVs) for HQs of 10, 5, and 3. The only ecological receptor that would be able to possibly dig through the 2 feet of soil cover is the grey fox. The fox, if present, is a predator for the salt marsh harvest mouse and as such, is trapped and removed from the site to protect the mouse. The City of Vallejo conducts weekly trapping for predator species on Mare Island, which has been in place and operating since the shipyard closed in 1996. The trapping is planned to continue. A monitoring plan implemented for protection of the cap will include provisions for trapping of deleterious animals should the City of Vallejo trapping fail or protection of the cap require expansion on the program.

6.2.1.3 Non-Tidal Wetland Areas Alternatives

All remedial alternatives provide protection to groundwater and human health. Table 6-1 shows the Human Health Risk Values for each alternative as a comparison. Ambient/background arsenic levels contribute most of the human health risk as can be seen by the lower cancer risk levels when calculated excluding the ambient/background arsenic contribution. Alternatives 2, 3, and 4 then rely on increasingly lower HQs (10, 5, and 3 respectively), resulting in a larger amount of material excavated, and protection for some species is slightly increased. Table 6-1 also shows the amount of material to be excavated for each alternative. However, the estimates are based on conservative estimates. For example the Killdeer HQ levels drive some removal of materials but are calculated at 100 percent range and diet in the contaminated area. This is very

conservative and the fact is that not all areas in the non-tidal wetland area would be typical Killdeer habitat. This leads to an increase in hot spots identified for species that may not match their current habitat. Alternative 5 (Institutional Controls, Hot Spot Excavation for a HQ of 1, and Monitoring) provides the most long-term effectiveness and permanence but results in the most temporary impacts to the wetland. Due to concerns related to the salt marsh harvest mouse, Alternative 5 may be required to meet the intent of the California and Federal Endangered Species Acts.

6.2.2 Reduction in Toxicity, Mobility, or Volume

6.2.2.1 Containment Area Alternatives

None of the alternatives provide for the reduction in toxicity or volume through treatment. Alternatives 2A and 2B provide reduction in mobility on-site by containing the refuse and contaminated materials with a cap (eliminating surface exposure) and preventing contaminated groundwater from moving off site through the Containment Barrier. Alternative 3 (off-site disposal) transfers the toxicity and volume to another site that may provide reduction in mobility at the ultimate disposal facility, depending on the implemented controls.

6.2.2.2 Upland Areas Alternatives

None of the five alternatives provide for the reduction in toxicity or volume through treatment. Alternatives 2, 3, 4, and 5 provide a reduction in mobility by removing soil hot spots and consolidating them within the Containment Area. In addition, the 2-foot cover provides reduction in mobility due to control of surface runoff.

6.2.2.3 Non-Tidal Wetland Areas Alternatives

None of the alternatives provide for the reduction in toxicity or volume through treatment. All alternatives provide a reduction in mobility by removing soil hot spots and consolidating them within the Containment Area.

6.2.3 Short-Term Effectiveness

6.2.3.1 Containment Area Alternatives

Alternatives 2A and 2B pose fewer risks to workers and the community because of the increased risks with excavation and transporting waste in Alternative 3. Alternatives 2A and 2B would not disturb the underlying waste and therefore the exposure risks are minimized. Approximately 50,000 truckloads of waste will be moved off site to another facility in Alternative 3, requiring up to 100 trucks per day during the construction season, over a 2 to 3 year period.

Alternatives 2A and 2B can be implemented faster than Alternative 3. Alternative 3 will take substantially more time to complete (approximately 2 to 3 years), generates truck traffic concerns, has more potential to generate odor, dust, and particulates, and is more likely to expose workers, and potentially the public, to hazardous materials, radiological items, and munitions or explosives of concern (MEC), if present.

6.2.3.2 Upland Areas Alternatives

Alternatives 2, 3, 4, and 5 have similar short-term effects, although Alternative 2 has slightly less impact due to the smaller volume of material removed. Alternative 5 has more severe short-term impacts due to the large amount of material required to be excavated. Table 6-1 shows the amounts of material to be excavated for each alternative.

6.2.3.3 Non-Tidal Wetland Areas Alternatives

Hot spot removal in Alternative 2 has relatively minor short-term impacts. Alternatives 3 and 4 have slightly increased short-term negative impacts to the wetlands and higher risks to workers than Alternative 2. All alternatives have some short-term impacts as they disturb areas of the wetlands. Each hot spot is approximately 50 feet by 50 feet and will be backfilled with wetland grade material after excavation. As each alternative successively increases the number of hot spots excavated, more restoration will be required; however, because each hot spot is relatively small, it is expected that the recovery time will be relatively short.

6.2.4 Implementability

6.2.4.1 Containment Area Alternatives

Alternatives 2A and 2B are readily implementable with standard technologies. Alternative 2B is slightly more difficult to implement as installing the GCL layer takes more care and the amount of acreage covered by the GCL will increase. Alternative 3 is much more difficult to implement as it requires many more resources, off-site transportation and disposal contracts, and significant hazardous waste handling; and inspection for radiological and MEC items.

6.2.4.2 Upland Areas Alternatives

Alternative 2 is slightly more easily implemented than Alternative 3, which is slightly more implementable than Alternative 4 due to the smaller amount of material removed, but all are implementable. Alternative 5 is much more difficult to implement due to the large amount of material required to be excavated and consolidated within the Containment Area.

6.2.4.3 Non-Tidal Wetland Areas Alternatives

Alternative 5 is the most difficult to implement due to the amount of material removed; however, all alternatives are implementable with each successive alternative requiring more effort with more material being removed.

6.2.5 Cost

Table 6-2 shows a summary of all total costs with the alternatives. Detailed cost estimates can be found in Section 5.

6.2.5.1 Containment Area Alternatives

Total costs for Alternative 2A, including operations and maintenance (O&M), are $31,300,000. Costs for implementing Alternative 2B are $2,700,000 more than 2A, totaling $34,000,000. Costs for implementing Alternative 3 are significantly higher, with a total of $218,201,000.

There will be less need for O&M with Alternative 3; however, the implementation cost is extremely high.

6.2.5.2 Upland Areas Alternatives

Total costs for Alternative 2, 3, and 4 are all similar with slightly higher costs for each successive alternative as they remove more material. The costs for all the Upland Areas are shown on Table 6-1 along with the amount of material to be excavated. The cost for Alternative 4 is $3,160,000 and the costs jump significantly for Alternative 5 at $19,181,000.

6.2.5.3 Non-Tidal Wetland Areas Alternatives

Total costs for all remedial Non-Tidal Wetland Areas alternatives are similar with each successive alternative costing slightly more than the previous due to increasingly greater amounts of material removed. Table 6-1 shows the costs and the amounts of material to be excavated. Total costs range from $104,000 for Alternative 2 to $365,000 for Alternative 5.

6.3 MODIFYING CRITERIA

State and community acceptance criteria are used for comparative analysis of remedial alternatives as CERCLA-recognized modifying criteria. State and community acceptance, which cannot be fully evaluated until after the public comment period, will be further evaluated after the public comment period.

6.4 RESULTS OF COMPARATIVE ANALYSIS

Results of the comparative analysis for all alternatives are summarized in Tables 6-3, 6-4, and 6-5, for the Containment Area, Upland Areas, and Non-Tidal Wetland Areas, respectively. Threshold criteria are shown with a “yes” or “no”, indicating whether or not the alternative meets the required threshold. The remaining balancing criteria are ranked using a scale of one through five, with the grade of one indicating that an alternative meets a criterion best. The alternatives have been ranked for the threshold and balancing criteria. Alternative 1 for each of the area

provides a basis for comparison against other alternatives. Table 6-2 summarizes the total costs for each alternative.

For the Containment Area, Table 6-3 shows that Alternatives 2A and 2B (capping) rate the highest among the alternatives. Alternative 2A an health and the environment. is moderately less expensive than Alternative 2B, provides long-term protection of human health and the environment, and is much more practical to implement than Alternative 3.

For the Upland Areas, Table 6-4 shows that Alternatives 2, 3, and 4 are roughly equivalent in overall effectiveness and have slight tradeoffs in implementability and cost. Alternative 5 provides long-term protection of human health and the environment but with many more short-term impacts, much higher costs, and a longer implementation time.

For the Non-Tidal Wetland Areas, Table 6-5 shows that as Alternatives 2, 3, and 4 increase in overall effectiveness, they have slight tradeoffs in implementability and cost. Alternative 5 provides long-term protection of human health and the environment but with much more short-term impacts and a slightly higher cost, this alternative is fully protective of the salt marsh harvest mouse.

The final remedies will be chosen after review of the FS and input from the State and the public on the proposed plan.

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