subject to BAAQMD regulations. Impacts to air quality, if any, under BAAQMD jurisdiction are likely to result from the implementation of remedial actions. Several BAAQMD rules and regulations may apply to remedial actions implemented. For example, impacted wastes and soil at the former ORP / Building 1 area may require control of particulates (Regulation 6), odorous substances (Regulation 7), organic compounds (Regulation 8, Rule 40), or hydrogen sulfide (Regulation 9, Rule 2).

The construction and operation of treatment systems that discharge emissions to the atmosphere may also be subject to permitting and the installation of air pollution controls. For example, air stripping and soil vapor extraction operations are subject to Regulation 8, Rule 47. BAAQMD rules and regulations are **action-specific ARARs** that are or may be **applicable** or **relevant and appropriate** for specific OARB locations.

6.7 REQUIREMENTS DETERMINED NOT TO BE ARARs OR TBCs

Some regulations and guidances that could be considered ARARs or TBCs were specifically excluded from the list of ARARs and TBCs for RAP sites and RMP locations at the OARB. These potential ARARs or TBCs, and the reasoning for exclusion, are described below.

6.7.1 Safe Drinking Water Act

The SDWA of 1974, as amended in 1977, 1986, and 1996, establishes minimum national primary drinking water standards known as federal Maximum Contaminant Levels or MCLs. Federal MCLs and MCLs established specifically for drinking water in California are regulated under Title 22 of the CCR. The NCP at 40 CFR §§300.430(e)(2)(i)(B)-(D) states that Maximum Contaminant Level Goals ("MCLGs"), established under the SDWA, that are set at levels above zero, will be attained by remedial actions for surface water or groundwater that are current or potential sources of drinking water. Remedial actions shall achieve MCLs for groundwater containing COCs that do not have MCLGs, or if the MCLGs have been set at zero. For groundwater containing COCs without non-zero MCLGs, MCLs, or state standards; freshwater quality criteria may be potential ARARs when that groundwater is discharged to surface water (U.S. EPA, 1991e). In addition to MCLGs and MCLs, U.S. EPA issues secondary MCLs. However, secondary MCLs are not enforceable and are therefore TBCs. Secondary MCLs are described in Section 6.7.1.2.

6.7.1.1 MCLGs and MCLs

U.S. EPA's Office of Water develops MCLGs as a required first step toward issuance of national primary drinking water standards. MCLGs are not enforceable under the SDWA. MCLGs are health goals that are set at levels at which no known or anticipated adverse human effects occur, and which allow for an adequate margin of safety. MCLGs are strictly health-based levels and are derived from relevant toxicological data (U.S. EPA, 2001g).

MCLs are federally enforceable limits for COCs in drinking water. The MCL for a given COC is set as close to the corresponding MCLG as feasible. When issuing an MCL, U.S. EPA identifies an analytical method with a reporting limit that is set according to the desired MCL. U.S. EPA also identifies the Best Available Technology ("BAT") for removing the chemical to attain the MCL (U.S. EPA, 2001g). Section 8.2.12 addresses BAT for chemicals found in groundwater at RAP sites and RMP locations at the OARB.

Although MCLs were used in Section 5 to identify COCs, MCLs and non-zero MCLGs are not considered potential ARARs or TBCs for RAP sites and RMP locations at the OARB because groundwater at the OARB does not meet federal or State of California criteria for potential drinking water supply. As discussed in Section 3.5.1, groundwater in the shallow water-bearing zone and underlying Merritt Sand is brackish. RWQCB has proposed that the Basin Plan been amended to de-designate municipal supply as a potential beneficial use of groundwater along the Oakland shoreline, including the OARB.

6.7.1.2 Secondary MCLs

Secondary MCLs are established under the SDWA to protect public welfare. Secondary MCLs apply to chemicals in drinking water that adversely affect its odor, taste, or appearance and therefore cause people to discontinue using the water. Secondary MCLs are desirable goals. They are not based upon direct adverse health effects and are not enforceable. Secondary MCLs are not included as a TBC because groundwater at the OARB is not a current or potential source of drinking water.

6.7.2 Proposition 65

In November 1986, California voters approved an initiative to address increasing concerns about exposure to chemicals. This initiative became *The Safe Drinking Water and Toxic Enforcement Act*, which is codified in 22 CCR §12000 et seq. The act, however, is better known by its name on the voter ballot, "Proposition 65."

Proposition 65 prohibits discharges of any chemical "known to the state to cause cancer or reproductive toxicity" to a potential source of drinking water. Proposition 65 also requires "clear and reasonable" warnings to be provided before a significant exposure to any of these chemicals can occur. Cal / EPA, Office of Environmental Health Hazard Assessment ("OEHHA") is responsible for determining and listing chemicals "known to the state to cause cancer or reproductive toxicity."

In addition, OEHHA calculates "no significant risk levels" for carcinogens or reproductive toxicants, which are promulgated in 22 CCR §§12705, 12709, and 12805. Regarding these calculations, OEHHA (1994) states:

> that no significant risk levels are intended to provide "safe harbors" for persons subject to the Act, and do not preclude the use of alternative levels that can be demonstrated by their users as being scientifically valid.

In other words, if potential exposure to carcinogens and reproductive toxicants at a site are less than the no significant risk levels, OEHHA has concluded no clear and reasonable warnings of exposure are necessary. Alternatively, persons can conduct their own risk assessments to take into account site-specific conditions and their effect on potential exposures to chemicals to determine if a significant risk level exists.

No significant risk levels for carcinogens represent the daily intake level calculated not to result in a risk greater than one excess case of cancer in 100,000 individuals (i.e., 10^{-5}) exposed over a 70-year lifetime. No significant risk levels for reproductive toxicants represent the no observable effect level for the reproductive toxicant divided by a safety factor of 1,000.

By its terms, Proposition 65 only applies to persons in the course of doing business. City government and any department thereof are specifically excluded from this designation (refer to California HSC § 25249.11). Proposition 65 is not included as an ARAR or TBC for RAP sites and RMP locations at the OARB.

6.7.3 Soil Lead Guidance for CERCLA Sites

In its *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* ("Soil Lead Guidance"), dated 14 July 1994, U.S. EPA recommends using a screening level of 400 mg/kg of lead in soil for residential areas at CERCLA sites. Residential areas with lead concentrations less than 400 mg/kg generally require no further action. However, U.S. EPA clarifies this finding by noting that further study may be warranted below the screening level in some special situations, e.g., wetlands, areas

with ecological risk, and areas of higher than expected human exposure. According to the guidance, lead is not anticipated to pose a threat to groundwater because it is usually immobile in soil. U.S. EPA's Soil Lead Guidance is not considered a TBC because no residential land use is planned for the OARB.

6.7.4 U.S. EPA Region IX Preliminary Remediation Goals

U.S. EPA Region IX PRGs are risk-based screening levels for evaluating chemical impacts to a site. Concentrations of chemicals detected at a site greater than their respective PRGs do not automatically trigger a response action. Instead, exceeding a U.S. EPA PRG suggests that further evaluation of the potential risks posed by chemicals at the site is appropriate (U.S. EPA, 2000b). Further evaluation may include additional sampling, consideration of naturally occurring or ambient levels of the chemicals in the environment, or performance of a more detailed risk assessment to account for site-specific conditions and determine if remedial actions are warranted.

U.S. EPA residential soil and tap water PRGs were used to identify COCs at the OARB. However, these PRGs are not appropriate cleanup levels because the OARB will be redeveloped for commercial and industrial purposes only and groundwater is not suitable for drinking water supply. Risk-based remediation goals have been calculated specifically for the OARB (Section 7.3). Therefore, U.S. EPA PRGs are not included as TBCs for RAP sites and RMP locations at the OARB.

6.7.5 California Native Plant Protection Act

The intent of the California Native Plant Protection Act is to preserve, protect, and enhance rare or endangered plants native to California. The Act forbids taking, possessing, or selling rare or endangered native plants unless authorized by an incidental take permit. The California Native Plant Protection Act is not considered an ARAR or TBC because vegetation at the OARB consists entirely of exotic or landscaped species.

6.7.6 Endangered Species Act

The federal Endangered Species Act ("ESA") requires consultation with the United States Fish and Wildlife Service, as appropriate, to ensure that remedial actions do not jeopardize the continued existence of threatened or endangered species, or adversely modify or destroy their habitats. Substantive requirements of the ESA include determining whether a threatened or endangered species, or their habitat, will be affected by a proposed response action.

The California Endangered Species Act ("CESA") generally parallels the main provisions of the ESA. California Department of Fish and Game must be consulted to ensure that remedial actions are not likely to jeopardize the continued existence of any endangered or threatened species, or result in destruction or adverse modification of essential habitat. The ESA and CESA are not considered ARARs or TBCs because no significant habitat exists in the upland areas of the OARB addressed by this RAP.

6.7.7 Marine Mammal Protection Act

The federal Marine Mammal Protection Act prohibits the taking, including harassment, of marine mammals, in the seas and on land. In the unlikely event that marine mammals would enter remedial areas, this Act prohibits their taking. The Marine Mammal Protection Act is not considered an ARAR or TBC because marine mammals do not inhabit the portion of the OARB subject to this RAP.

6.7.8 Executive Order 11990, Protection of Wetlands

Executive Order 11990 and 40 CFR §6.302(a) require federal agencies conducting certain activities to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands. U.S. EPA must determine if the proposed actions will affect wetlands, and if so, the responsible agency must perform a wetlands assessment, which will be part of the environmental assessment or environmental impact statement. Adverse impacts shall be either avoided or minimized if no practicable alternative to the action exists. As discussed in Section 3.3, two small, non-jurisdictional wetlands are situated off-site east of Building 991. No wetlands are present on the OARB. Federal and State of California wetland regulations do not pertain to the OARB and are not considered ARARs or TBCs.

6.7.9 Stream and Wildlife Protections

Specific sections of federal law and the California Fish and Game Code seek to protect streams and wildlife. These provisions include requiring state or federal agency consultation if stream realignment or modification is proposed; prohibiting dumping of materials into waters of the state; and restricting certain means of "taking" birds or animals. These requirements are not considered ARARs or TBCs because no streams or significant habitat exist in the upland areas of the OARB addressed by this RAP.

7

7. REMEDIAL ACTION OBJECTIVES

The NCP, at 40 CFR §300.430(a)(1)(i), explains that the goals of the remedy selection process under CERCLA are to develop and implement remedial actions that protect human health and the environment, maintain protection over time, and minimize untreated waste. To help meet these goals, remedies for contaminated sites are selected that will achieve medium-specific RAOs.[17] RAOs provide the foundation upon which remedial alternatives are assembled.

RAOs should consider potentially complete exposure pathways as well as chemical-specific ARARs and risk-based remediation goals because protectiveness may be achieved by either preventing exposure (such as capping an area or limiting access) or by reducing contaminant concentrations (U.S. EPA, 1988a). In addition, RAOs should allow evaluation of remedial alternatives that will achieve cleanup levels associated with the reasonably anticipated land use of the site in question (U.S. EPA, 1995d). To facilitate understanding the RAOs established for the OARB, a conceptual site model of the OARB is described in Section 7.1. Section 7.2 presents RAOs for OARB. Section 7.3 discusses the methodology employed to calculate site-specific, risk-based remediation goals that serve as the basis for many of the remediation goals adopted for RAP sites and RMP locations at the OARB. Section 7.4 summarizes the remediation goals adopted for the OARB. Section 7.5 summarizes protocols for determining compliance with risk-based remediation goals at identified RAP sites and RMP locations at the OARB using available analytical results or new data obtained as part of additional investigations or collection of confirmation samples after implementation of remedial actions.

7.1 OARB CONCEPTUAL SITE MODEL

In most instances, contamination of soil and groundwater at the OARB is relatively minor because Army operations were limited chiefly to warehousing and shipping of cargo overseas and did not include the kind of manufacturing activities that occurred at many other, larger military bases. Identified chemical impacts derive mostly from the use of petroleum products for activities that supported the OARB's primary military mission as a distribution center. With few exceptions, chemical impacts are limited to soil beneath the specific buildings and locations where activities took place.

[17] Potentially affected media at a given site may consist of soil, groundwater, surface water, and air.

The high molecular weight and weathered petroleum hydrocarbons found in soil at the OARB are relatively immobile and, except possibly where used oil was stored, do not contain appreciable amounts of other contaminants, such as VOCs, PAHs, or metals that would constitute a human health risk. No non-aqueous phase liquid ("NAPL") or heavily contaminated soil that may leach COCs and act as ongoing contaminant sources have been identified at RAP sites at the OARB involving areas of VOC-impacted groundwater (i.e., eastern end of Building 807, near Buildings 808 and 823, and near Building 99). Significant migration of COCs in groundwater has not occurred anywhere on the OARB. The extent of impacted groundwater appears to be limited to portions of the shallow water-bearing zone entirely within the property boundary of the OARB. Refer to Sections 3.5 and 4.4.4.10 for a discussion of shallow groundwater conditions at the OARB.

The former ORP / Building 1 area is unique in that the tarry residue constitutes the only principal threat waste known to exist at the OARB. The tarry residue is considered to be a principal threat waste because it can be very acidic. A pH of 1 has been measured for some samples of this material. In addition, lead, PAHs, PCDDs, and PCDFs have been detected in the tarry residue at concentrations of concern. The concept of principal threat waste is discussed in greater detail in Section 8.1.

Buildings, railroads, roadways, and paved parking or storage areas now cover the OARB and will in the future under the Amended Reuse Plan. As a consequence, no significant ecological habitats exist in the upland areas of the OARB subject to this RAP. High TDS in the shallow water-bearing zone and underlying Merritt Sand render groundwater at the OARB unsuitable for drinking water supply.

The Amended Reuse Plan outlines redevelopment of the OARB for commercial and industrial purposes only. The OARB after redevelopment will continue to provide barriers to human contact with surface soil through existence of buildings, paving, roads, and landscaped areas. The only exception is for potential exposures related to construction or maintenance work when such barriers are penetrated under protocols allowed by the RMP. Potentially exposed future populations consistent with this site conceptual model are discussed in Section 7.3.1.

7.2 REMEDIAL ACTION OBJECTIVES

To attain the NCP goals of implementing remedial actions that protect human health and the environment, maintain protection over time, and minimize untreated waste, the

remedial action objectives ("RAOs") for soil and groundwater associated with OARB property to be transferred to OBRA by the EDC are:

- Establish media-specific individual remediation goals that correspond to a Hazard Index ("HI") of 1 for each non-carcinogenic COC identified at the OARB. Remedial actions implemented at each RAP site or RMP location will be designed to meet individual non-carcinogenic COC remediation goals as established in Section 7.3, unless the cumulative non-carcinogenic risk goal as defined in this RAP can be met by alternative concentration limits demonstrated for a specific RAP site or RMP location to the satisfaction of DTSC. When multiple non-carcinogenic COCs are identified at a specific RAP site or RMP location, the cumulative non-carcinogenic target hazard index can be met by determining aggregate non-carcinogenic risk using the protocols in Section 7.5. Once remediation activities for a RAP site or RMP location have been completed pursuant to the RAP and RMP, confirmation samples will be collected to verify the cumulative non-carcinogenic hazard index of COCs (associated with the potentially complete exposure pathways defined in this RAP) remaining in soil and groundwater at each RAP site or RMP location will not exceed a cumulative HI of 1. The individual remediation goals for non-carcinogens in Table 7-11 represent the maximum allowable concentrations for the respective COCs. However, these remediation goals can be adjusted downward, as needed, if the total HI exceeds 1.

- Establish media-specific individual remediation goals that correspond to a 10^{-6} incremental lifetime cancer risk for each potential carcinogenic COC identified at the OARB. Remedial actions implemented at each RAP site or RMP location will be designed to meet individual carcinogenic COC remediation goals as established in Section 7.3, unless the cumulative carcinogenic risk goal as defined in this RAP can be met by alternative concentration limits demonstrated for a specific RAP site or RMP location to the satisfaction of DTSC. When multiple carcinogenic COCs are identified at a specific RAP site or RMP location, the cumulative carcinogen target risk level can be met by determining aggregate carcinogenic risk using protocols and equations provided in Section 7.5. Once remediation activities for a RAP site or RMP location have been completed pursuant to the RAP and RMP, confirmation samples will be collected to verify the cumulative carcinogenic risk of COCs (associated with the potentially complete exposure pathways defined in this RAP) remaining in soil and groundwater at each RAP site or RMP location will not exceed a cumulative, incremental lifetime human health carcinogen target risk level of 10^{-5}. As discussed in Section 7.3.3.2, the cumulative, incremental lifetime carcinogen

target risk level of 10^{-5} is determined to be appropriate for the OARB after considering the applicability of the full risk range acceptable under the NCP and the cumulative carcinogenic risk goal of 10^{-6} as used by DTSC as the "point of departure" for evaluating remedial alternatives at sites in California under Chapter 6.8 of the HSC. The individual remediation goals in Table 7-11 represent the maximum allowable concentrations for the respective COCs. These remediation goals will not be increased to allocate amongst the residual COCs to meet the overarching cumulative risk of 10^{-5}. However, these remediation goals can be adjusted downward, as needed, if the total cancer risk level exceeds 10^{-5}.

- Establish a remediation goal for lead that does not exceed a blood lead concentration greater than 10 micrograms per deciliter ("µg/dl") at the 99th percentile in potentially exposed individuals resulting from the total exposure to lead at OARB locations and to naturally occurring lead in the environment (e.g., air, food, water) as calculated using the DTSC Lead Spread 7.0 computer model or a more stringent site-specific lead goal determined appropriate for OARB.

- Remove, or remove and treat, source material (i.e., principal threat waste) that poses significant human health or environmental threats or is prone to continued leaching of COCs to groundwater.

Action-specific, base-wide RAOs for soil and groundwater at RAP sites and RMP locations predicated on the above aims are as follows:

Soil RAOs:

- Maintain existing conditions at the OARB to prevent direct contact with known or potentially impacted soil prior to implementation of remedial actions or redevelopment.

- Specifically for the ORP / Building 1 area, remove, or remove and treat, tarry residue at ORP / Building 1 area to eliminate hazards associated with this source material and to allow planned land uses consistent with the Amended Reuse Plan.

- Remove or treat impacted soil that interferes with planned land uses, or is encountered during redevelopment or through post-redevelopment activities, or as otherwise necessary to achieve site-specific, soil remediation goals designated in the RAP.

- Contain impacted soil that will not unreasonably interfere with planned land uses by maintaining existing cover or constructing new cover.

Groundwater RAOs:

- Implement institutional controls, alone or in combination with site-specific engineering controls as part of all selected remedies, to prevent incidental ingestion or dermal contact with impacted groundwater under existing and planned land uses consistent with the Amended Reuse Plan.

- Treat VOC-impacted groundwater that interferes with planned land uses or as otherwise needed to achieve site-specific, groundwater remediation goals, or apply engineering controls to new structures to allow planned redevelopment or as otherwise necessary to reduce potential exposure posed by vapor intrusion to the target risk levels stated above.

- Prevent further significant increases of concentrations of metals and other non-volatile COCs in groundwater.

The site-specific numerical remediation goals for COCs in soil and groundwater determined to be consistent with these RAOs are discussed below.

7.3 RISK-BASED REMEDIATION GOALS

According to U.S. EPA (1991a), the NCP establishes two sources that can be used to establish cleanup levels that remedial actions must achieve. These sources consist of chemical-specific ARARs, and risk-based remediation goals. Except for PCBs, lead, and asbestos, chemical-specific ARARs do not exist that adequately consider the scenarios under which humans (e.g., future on-site commercial and industrial workers) may be exposed to COCs in soil and groundwater at the OARB. The chemical specific ARARs for PCBs, lead, and asbestos are generally not as protective as the risk-based remediation goals contemplated in this RAP and are, therefore, not useful in establishing remediation goals. In the absence of useful chemical specific ARARs, risk-based remediation goals to protect human health have been derived in this RAP. These human health risk-based remediation goals serve as numerical values intended to achieve certain RAOs defined in Section 7.2. Ecological remediation goals were not determined because the upland areas of the OARB do not now, and are not anticipated in the future, to sustain any biologically

significant populations of plants, soil fauna, wildlife, or aquatic life.[18] Selected submerged areas of land to be transferred to OBRA via the EDC (i.e., marine sediments within former BRAC Parcels 2 and 3) have been evaluated by ecological risk assessments completed by the Army and are discussed in Section 4.4.4.9 of this RAP.

U.S. EPA (1991a) defines remediation goals as "concentration goals for individual chemicals for specific medium and land use combinations at CERCLA sites." U.S. EPA (1991a) discusses development of preliminary remediation goals, commonly referred to as PRGs, that can be finalized as site-specific numerical remediation levels or goals upon approval of the remedy. As U.S. EPA (1991a) explains:

> Final remediation levels are not determined until the site remedy is ready to be selected; final remediation levels are then set out in the ROD. PRGs are refined into final remediation goals throughout the process leading up to remedy selection. The ROD itself, however, should include a statement of final clean-up levels based on these goals, as noted in NCP Section 300.430(e)(2)(i)(A).[19]

In other words, numerical, risk-based remediation goals are site-specific cleanup levels that are derived specifically for a given property. Remediation goals take into account the COCs that have been identified, media that have been impacted, most likely future land use, and pathways and conditions under which exposure may occur at a particular property. In addition, remediation goals are calculated by establishing acceptable or target risk levels that will protect potentially exposed individuals from the non-carcinogenic and carcinogenic effects of COCs. The procedures and assumptions used to derive remediation goals for the OARB are discussed in Sections 7.3.1 through 7.3.6. Identified COCs for the OARB are discussed in Section 5.

7.3.1 Potentially Exposed Populations

Based on the redevelopment strategy for the OARB presented in the Amended Reuse Plan, the primary, on-site future populations or human receptors that may be potentially exposed to COCs in soil or groundwater consist of the following:

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[18] DTSC (2000b, 2000d) has concurred that the minimal habitat at the OARB does not warrant an assessment of ecological effects. Off-site areas near the OARB (i.e., spit and adjacent marine sediments in the Oakland Outer Harbor) where biota may be impacted will be addressed separately by others and are not included in this RAP except for the submerged areas of former BRAC parcels 2 and 3 included in the EDC property transferred to OBRA as discussed in this RAP in Section 4.4.4.9.

[19] This RAP will establish the remediation goals for the OARB in lieu of a ROD.

During Redevelopment:

- Construction workers that will conduct on-site earthwork activities as part of redevelopment ("earthwork construction workers").

After Redevelopment:

- Tenants that will occupy commercial space upon redevelopment ("indoor commercial workers").
- Tenants that will work outdoors and perform industrial activities such as loading, unloading, and transporting of cargo containers ("outdoor industrial workers").
- Groundskeepers, utility maintenance workers, and other personnel that will maintain the new improvements at the OARB ("maintenance personnel").

The measures implemented to protect these core users of the OARB will also safeguard occupants of adjacent properties and infrequent visitors who have a significantly lower potential for exposure to COCs in soil and groundwater at the OARB.

7.3.2 Potential Exposure Pathways

The four potentially exposed populations identified in Section 7.3.1 could be exposed to COCs in soil or groundwater by the complete or potentially complete exposure pathways identified on Figure 7-1. Each of the pathways shown on this figure are discussed in the sections below. Risk-based remediation goals have been calculated only for those pathways that are judged to be complete or potentially complete, and where resultant exposure to COCs by the pathways will contribute appreciably to the potential overall risk to the individual in question.

The identified, potentially complete exposure pathways coupled with the four potentially exposed populations constitute the four exposure scenarios evaluated in detail in this RAP and used for determination of the risk-based, numerical remediation goals as required by the stated RAOs. All four exposure scenarios recognize that cover materials will be used to minimize human contact with surface soil as a component of all remedial actions in this RAP. The required use of cover materials (e.g., paving, engineered clean fill in landscaped areas, building foundations, or ballast in rail areas) renders most exposure pathways incomplete for the typical on-site worker. For example, indoor commercial workers and outdoor industrial workers are assumed to have no direct contact with surface soil, no ingestion of surface soil, and no inhalation of surface soil under their typical work day routines because all surface soil will be covered by materials that prevent contact with such

soil. Earthwork construction workers and maintenance personnel have limited exposures by these pathways before installation of cover materials are complete (i.e., during construction for redevelopment) or when cover materials are penetrated (i.e., intermittent utility repair or maintenance activities in the future).

Appendix C quantifies the risks for the hypothetical exposure pathway of an outdoor industrial worker scenario where no cover materials are assumed (i.e., "bare dirt" outdoor industrial worker scenario). The "bare dirt" outdoor industrial worker scenario assumes that workers are present for 25 years on the OARB with exposed surface soil and no cover materials, which is not currently the case nor will be the case in the future. Under such a scenario, as evaluated in Appendix C, all typical dirt contact, ingestion, and inhalation pathways are assumed to be complete. The resultant, calculated health-protective concentrations for many COCs under the bare dirt outdoor industrial worker scenario are more stringent (e.g., approximately one-third of the total COCs are less than the adopted remediation goals for the OARB described in Section 7.4). Risk-based numerical remediation goals calculated for such a scenario are, thus, illustrative of the protective effects of incorporating required cover materials as part of all remedial actions for the OARB considered in this RAP. These hypothetical risk calculations provide a gauge of the sensitivity of these risk evaluations to potential failures in the permanence or long-term effectiveness in a barrier-type remedy.

7.3.2.1 Vapor Intrusion and Inhalation of Volatile COCs in Groundwater

Except for the former ORP / Building 1 area, available analytical results do not indicate that significant, residual sources of volatile COCs exist in soil at the OARB. However, chlorinated VOCs are present in groundwater at the eastern end of Building 807, near Buildings 808 and 823, and near Building 99. BTEX and MTBE due to petroleum fuel releases are found in groundwater near tank location 11A/12A/13A.

All compounds detected in soil or groundwater at the OARB that met the U.S. EPA Region IX (2000b) definition of a volatile compound[20] were evaluated for vapor intrusion to indoor air. These compounds include all the VOCs listed in Tables 5-2 through 5-5 and the SVOCs acenaphthene, anthracene, fluorene, phenanthrene, and pyrene. Under circumstances where there are discoveries of extremely high concentrations of certain low volatility compounds (e.g., PCBs, aldrin, alpha BHC, or gamma BHC – see Appendix C), evaluation of potential volatilization and related exposure pathways may be required. Thus, newly detected contamination of separate phase organics or other

[20] Volatile compounds are defined to be chemicals with a Henry Law constant greater than 10^{-5} atm-m^3/mol and a molecular weight less than 200 consistent with criteria used by U.S. EPA Region IX (2000b).

principal threat levels of potential COCs of even low volatility should be evaluated for vapor risks.

Volatile compounds theoretically have the potential to volatilize into pore spaces within unsaturated soil above the groundwater surface and migrate through diffusion and advection (i.e., air currents) to enter buildings by a mechanism referred to as vapor intrusion. Vapor intrusion is typically assumed to occur through foundation cracks or gaps caused by penetrations through the foundation.

Vapor intrusion begins when volatile COCs in groundwater partition into soil gas in the subsurface. The magnitude to which these compounds partition or volatilize into soil gas depends on the properties of the chemical. Chemicals with higher vapor pressures, lower water solubilities, and lower affinities for sorption to soil, partition into soil gas to a greater extent than other chemicals that do not have these properties. VOCs, BTEX, and MTBE partition readily into soil gas.

Once in soil gas, volatile COCs may migrate upwards or laterally by both diffusion and advection. Diffusion refers to the migration of chemicals from areas of high chemical concentration to areas of low chemical concentration. Diffusion is a relatively slow transport process as compared to advection, which occurs when soil gas containing volatile compounds is induced to migrate by pressure gradients.

Soil gas containing volatile COCs may migrate into a building by diffusing through cracks in the foundation slab. Lower pressure inside a building may also sweep soil gas into the building through cracks by advection. The phenomenon of a lower pressure inside a building is sometimes referred to as a "stack effect." A stack effect can be caused by:

- Warmer air inside the building, which tends to rise and draw air from the lower parts of the building.
- Wind, which tends to impart a lower pressure inside the building.
- Manufacturing equipment exhausts, which tend to draw air into the building and lower the interior pressure.
- Mechanical ventilation systems, which induce a slight negative pressure inside the building.

Vapor intrusion is the primary potentially complete exposure pathway that could affect indoor commercial workers at the OARB. Diffusion can also result in migration of volatile COCs to ground surface where no buildings exist and lead to potential exposures to individuals working outdoors (i.e., earthwork construction workers, maintenance personnel, and industrial workers). However, dilution caused by wind renders the potential for outdoor exposure less than the chance of indoor exposure. Remediation goals have been calculated for the indoor commercial worker, which will protect all identified future populations (as indicated on Figure 7-1) from exposure by the volatilization pathway.

7.3.2.2 Ingestion of and Dermal Contact with COCs in Groundwater

As discussed in Section 3.5.1, high TDS concentrations in the shallow water-bearing zone and Merritt Sand beneath the OARB render the groundwater unusable for drinking water supply. MCLs are not considered ARARs because groundwater at the OARB is not a current or potential source of drinking water. Relevant remediation goals for groundwater are, foremost, the concentrations of volatile COCs in groundwater determined not to pose an unacceptable vapor intrusion risk. Despite the poor quality of groundwater, individuals could be exposed to contaminated groundwater through incidental ingestion or dermal contact if wells were constructed at the OARB to provide water for landscape irrigation, water features, or other purposes. Remedial actions must therefore include institutional controls, alone or in combination with engineering controls, to ensure exposure does not take place by these pathways.

Earthwork construction workers and maintenance personnel can also ingest or absorb COCs in groundwater as a result of incidental contact during dewatering or trenching that may result in exposure to contaminated groundwater. However, on the basis of sensitivity calculations provided in Appendix C, such infrequent, hypothetical exposures by ingestion of or dermal contact with COCs in groundwater are judged to be insignificant when compared to exposure to COCs in soil that may be experienced by these same individuals, as described in Section 7.3.2.3. Such infrequent, hypothetical exposure to COCs in groundwater by these pathways will be mitigated by incorporating appropriate health and safety requirements into activities that may involve contact with contaminated groundwater, consistent with protocols in Section 6.1 of the RMP.

Appendix C provides a sensitivity analysis for infrequent but possible encounters with shallow groundwater by earthwork construction workers and maintenance personnel. The sensitivity analysis indicates that, given groundwater conditions at OARB, occasional contact with groundwater does not result in significant incremental health risks for earthwork construction workers or maintenance personnel. Thus, to simplify the

effort of calculating remediation goals, contact with contaminated groundwater has not been incorporated into the exposure pathways for the earthwork construction worker or maintenance personnel.

7.3.2.3 Incidental Ingestion of and Dermal Contact with, and Inhalation of COCs in Soil

Earthwork construction workers and maintenance personnel may also be exposed to COCs through incidental ingestion, dermal contact, and inhalation of contaminated soil and volatile chemicals when digging below cover materials that now exist or will be constructed in connection with redevelopment of the OARB. Incidental ingestion occurs primarily through hand-to-mouth contact with contaminated soil and absorption of COCs into the bloodstream. Dermal contact occurs when contaminated soil adheres to exposed skin and COCs are absorbed through the dermis into the bloodstream. Inhalation occurs when wind or human activities suspend contaminated soil into the air, and human receptors subsequently inhale these dirt particles. Earthwork construction workers or maintenance personnel may also potentially inhale VOCs, BTEX, or MTBE if excavation or disturbance of soil and groundwater causes increased volatilization of these chemicals within the work zone. Remediation goals have been calculated to protect earthwork construction workers and maintenance personnel from exposure by incidental ingestion, dermal contact, and inhalation of contaminated soil or VOCs that become airborne due to contact with such soil.

7.3.2.4 Ingestion and Dermal Contact of Surface Water Impacted by COCs

Contaminated soil on the OARB is covered by existing improvements at the OARB. The potential for rainfall or non-stormwater related surface flows to become contaminated by soil are limited. The OARB will remain covered by buildings, roadways, and pavement after redevelopment. No potentially complete exposure pathways to surface water impacted by COCs exist now or are likely to exist in the future. Remediation goals for surface water have not been calculated in this RAP.

7.3.2.5 Ingestion of COCs in Homegrown Produce

Ingestion of COCs in homegrown produce is final pathway that is included by DTSC in computer models such as Lead Spread. Plants may uptake contaminants in soil that become incorporated in fruits and vegetables that are eventually eaten by humans. This pathway is not considered complete because no gardens presently exist at the OARB, and the anticipated commercial and industrial uses for the OARB make growing of produce

on-site highly unlikely in the future. No site-specific remediation goals including this pathway have been calculated in this RAP.

7.3.2.6 Leaching to Groundwater

Leaching of chemicals from vadose zone soils to groundwater is a pathway that is included in *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Groundwater* (commonly referred to as "RBSLs"); (RWQCB, 2001b). In the absence of site-specific remediation goals for soil to protect against leaching to groundwater, soil leaching screening levels to protect against non-drinking water sources from Table G of the RBSLs have been used as place holders in Table 7-10, and in cases where these leaching values were lower than any human risk-based remediation goals, the leaching values were carried over to Table 7-11 as final remediation goals. A more detailed, site specific fate and transport evaluation should be considered if these leaching values are found to govern the need for future remediation at RAP sites or RMP locations.

7.3.3 Target Risk Levels

Target risk levels have been established to protect individuals from potential non-carcinogenic and carcinogenic effects of potential chronic exposures to COCs identified at the OARB. A target risk level for lead has also been identified. Lead is considered separately because , although lead affects target organs (e.g., central nervous system) which are affected by other toxicants, the studies in the literature associate the toxicity of lead with blood lead concentration, rather than the applied dose. Hence, a separate modeling approach is utilized to determine an acceptable lead exposure as described in Section 7.3.3.3.

7.3.3.1 Non-carcinogen Target Risk Level

As defined by U.S. EPA (1989d), non-carcinogenic health effects are organ-specific and are manifested only after reaching a certain chemical dose. As a result, a range of exposures exists from zero to some finite value that can be tolerated with essentially no chance of adverse effects. The upper bound on this tolerance range or "safe dose" is identified as a reference dose ("R*f*D").

U.S. EPA (1989d) estimates the potential for non-carcinogenic effects by comparing a site-specific exposure level (i.e., estimated daily dose) over a specified time period (i.e., chronic exposure greater than 7 years) with a reference dose derived for a similar exposure period. This ratio of estimate dose to toxicity reference dose is called the HI.

Consistent with the NCP at 40 CFR §300.430(e)(2)(i)(A)(1), U.S. EPA (1991a) established the standard default non-carcinogenic cumulative target risk level to correspond to a HI of unity (i.e., 1). This target risk level is used to calculate a chemical-specific concentration that equates to the estimated dose from all significant exposure pathways in a given medium below which it is unlikely, even for sensitive populations, to experience adverse health effects. Where multiple COCs are involved, these non-carcinogenic effects can be assumed to be additive and apportioned among several COCs so that the cumulative HI is less than 1.

The remediation goal for an individual non-carcinogenic COC at the OARB is based upon a HI of 1 consistent with the RAOs in Section 7.2. An overarching RAO of a HI of 1 is adopted as the cumulative hazard index for non-carcinogenic COCs at each OARB location. When multiple non-carcinogenic COCs are identified, the overarching RAO of HI equal to 1 can be met by determining the cumulative hazard index, using protocols and equations provided in Section 7.5, for a specific RAP site or RMP location.

7.3.3.2 Carcinogen Target Risk Level

Carcinogenesis, unlike non-carcinogenic health effects, is generally thought to be a phenomenon for which risk evaluation based on presumption of a threshold is inappropriate (U.S. EPA, 1989d). For carcinogens, U.S. EPA assumes that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and eventually to a clinical state of disease. This hypothesized mechanism for carcinogenesis is referred to as "non-threshold" because there is no level of exposure to such a chemical that would not pose a finite probability, however small, of generating a carcinogenic response. No dose is thought to be risk-free. Therefore, in evaluating cancer risks, a safe dose cannot be estimated according to U.S. EPA guidance. Although this issue is subject to scientific debate, U.S. EPA guidance was followed in determining a carcinogenic target risk level for calculating risk-based remediation goals for the OARB.

For carcinogenic effects, U.S. EPA uses a two-part evaluation. In the first part of this evaluation, the chemical is assigned a weight-of-evidence classification, which is related to how convincingly the scientific studies demonstrate that the chemical is carcinogenic to humans. In the second part of this evaluation, a slope factor ("SF") is calculated, which is a measure of the chemical's potency. U.S. EPA (1989d) estimates risks as the incremental probability of an individual developing cancer over a lifetime as a result of any short-term or long-term exposure to the potential carcinogen. This probability is defined as the incremental or excess lifetime cancer risk. The SF is expressed the

95 percent upper confidence limit (i.e., 95% UCL) on the slope of the low-dose linear portion of the dose-response curve as estimated by the multistage linear model. The SF directly relates the incremental risk of cancer over a lifetime (i.e., 70 years) to the degree of chemical exposure averaged over a lifetime.

This potential carcinogenic risk can be summed across potential exposures to multiple chemicals, where such exposures are conservatively assumed to be possible. A scientifically correct procedure would be to add the risk of each chemical that is believed to have the same manifestations of carcinogenic effect in humans (i.e., target organs). However, as a conservative, health-protective step, the risks due to all potentially carcinogenic chemicals are assumed to be additive without consideration of target organs. The target risk level is termed "cumulative" when summed across all chemicals and pathways.

Consistent with DTSC procedures for determining remedies at contaminated sites in California, a range of possible cumulative carcinogen target risk levels are considered in this RAP as discussed below.

- The NCP, at 40 CFR §300.430(e)(2)(i)(A), provides a definition of an acceptable residual cancer risk range of 10^{-6} through 10^{-4} for the remedy selection process under CERCLA to develop and implement remedial actions that protect human health and the environment. U.S. EPA (1991g) has stated that remediation is generally not warranted for contaminated property if the cumulative cancer risk is less than 10^{-4}. If remediation is undertaken at such a site, U.S. EPA (1991g) has expressed a preference for cleanups that achieve the lower end of this target risk range. However, U.S. EPA (1991g) acknowledges that remedial actions that achieve reductions in site risk anywhere within the 10^{-6} through 10^{-4} risk range may be acceptable after considering site-specific conditions.

- Under Chapter 6.8 of the California HSC, DTSC utilizes a cumulative risk of 10^{-6}, in either an industrial or residential exposure scenario, as a point of departure for evaluating remedial actions at contaminated sites in California, i.e., a preference for achieving cleanups at the lower end of the NCP's acceptable range. DTSC evaluation procedures allow selection of remedies that are designed to achieve residual risks within the NCP's acceptable range, but greater than the point of departure after considering site-specific factors. Such factors are generally site conditions or uses that enhance DTSC's confidence in calculated residual risks. The discussion of the conceptual site model in Section 7.1 identifies several unique factors about the OARB and its

planned reuse that allow for remediation goals calculated for an industrial exposure scenario, and for consideration of cancer risk target levels, on a site-wide basis, within the NCP acceptable risk range but above the point of departure. These factors include the following:

- The planned reuse of the OARB is for commercial and industrial redevelopment base-wide in accordance with the Amended Reuse Plan. The future land uses on the southern portion of the OARB will be intermodal transportation operations of the Port of Oakland in the PDA. These future PDA uses and activities will include extensive areas covered with thick concrete-interlocking slabs designed to support stacked shipping containers and redesigned, adjacent railroad tracks and railyards covered with ballast or paving. The commercial areas on the northern and western portions of the OARB will be the GDA consisting of new paved roadways, paved parking areas, sidewalks, filled and landscaped areas, and commercial building foundations. All of these site improvements will provide barriers to human contact or other exposures to existing on-site soils, under planned typical commercial and industrial uses.

- Shallow groundwater at the OARB is not currently utilized for domestic supply under policies and guidance of the RWQCB and SWCRB. Planned future uses of the OARB property will be accompanied by specified use restrictions on the land and on use of shallow, on-site groundwater. These use restrictions will be implemented through remedies selected in this RAP and through building permit controls implemented under the City of Oakland's ULR Program. Human exposures to existing site soils and groundwater will not occur except potentially as contemplated for construction and maintenance personnel. All potentially exposed personnel will follow the risk management protocols that will include the worker protective measures described in the RMP (Appendix E), a component of all remedies recommended in this RAP.

- Outside of the RAP sites, the residual concentrations of COCs detected in on-site soils or shallow groundwater generally result in estimated risk to human health that fall within the NCP risk range for industrial exposure scenarios (see prior Army risk assessments prepared for various areas of the OARB).

Site-specific factors that support deviation from the 10^{-6} point of departure include the following:

- An extensive site use history is available for the OARB coupled with a substantial database of laboratory analytical results that define the general nature of residual COCs found on-site. With the exceptions of certain areas identified herein as RAP sites, most areas of the OARB have been found to have low concentrations of low threat COCs consisting largely of petroleum hydrocarbons and related constituents or relatively non-mobile, non-volatile metals and SVOCs.

- As identified in this RAP, RAP sites (i.e., known areas on the OARB of significant releases of COCs) will be actively remediated to remove residual source materials.

- Most remaining areas of the base, including identified RMP locations, have primarily known or suspected releases of petroleum hydrocarbons and its constituents, or low mobility, low volatility constituents like metals and SVOCs that can be readily addressed by planned RMP protocols.

- Measurable concentrations of COCs in many areas of the base are expected to decline over time as a result of planned remedial actions due to natural attenuation of many organic COCs.

- Achieving lower residual concentrations of certain COCs in an effort to attain carcinogen risk targets at the lower end of the NCP acceptable risk range (i.e., the point of departure) would be difficult and costly, given the nature of the fill materials used to construct much of the OARB.

- Achieving consensus among stakeholders on what degree of residual contamination constitutes an acceptable risk is one of the factors in determining remediation goals for potential carcinogens. In particular, U.S. EPA (2002b) finds that community members provide crucial insight into "public values and perceptions on the risk of concern, the preliminary remedial actions being considered and public acceptance of those remedies." Through its ULR program (Oakland, 2000), the City of Oakland has explored the issue of acceptable risk with the Oakland community, and representatives of federal, state, and local regulatory agencies charged with enforcing

environmental regulations. The DTSC believes that the City of Oakland dialogue bears on the discussion of acceptability of deviation from the point of departure.

In 1996, staff from the City of Oakland Environmental Services Division met with representatives of the West Oakland Environmental Justice Pilot Project, the Mayor's office, and the Rose Foundation. The purpose of this meeting was to determine what kind of feedback was desired from the community and which types of individuals and organizations should convene the Community Review Panel to evaluate the objectives of the ULR program. On the basis of the meeting, several organizations were contacted directly and a public notice soliciting applications for membership on the panel was published in the *Oakland Tribune* on July 31, 1996. Members of the Community Review Panel ultimately included individuals from the African American Development Association, GEI Consultants, People United for a Better Oakland, Northern California Minority Business Opportunity Community, Sierra Club, Urban Habitat Program, and Uribe & Associates. The panel met twelve times between September 1996 and July 1997 and presented its recommendations in the Community Review Panel report, dated August 7, 1997, entitled *Consensus Recommendations for Implementing the Oakland Urban Land Redevelopment Program* (Oakland, 1997).

Although the panel expressed that the ideal outcome would be the removal of all contaminates from Oakland communities, the panel asserted that the resources to achieve this ideal simply do not exist. The panel concluded that stalling redevelopment will likely result in a greater public health threat, and larger environmental, social, and economic costs to the affected community compared with implementation of risk-based cleanup. The Community Review Panel therefore recommended that the ULR program adopt cleanup levels based upon conservative assumptions that do not result in an incremental lifetime cancer risk greater than 10^{-5} (one in 100,000 potentially exposed individuals).

The recommendations of the Community Review Panel ultimately led the City of Oakland to include a set of tiered cleanup levels into the ULR program as discussed in Section 6.6.1.4. Tier 1 presents a conservative, health protective set of cleanup levels that are based on an individual COC "target" risk of 10^{-6}. Tier 1 cleanup levels apply to properties where information on environmental conditions is limited. Tier 2 cleanup levels are based on a target risk of 10^{-5}. Tier 2 cleanup levels generally apply to properties where geologic and

hydrogeologic conditions and uses are better understood. Tier 3 analysis requires performance of a site-specific risk analysis with input parameters appropriate for planned uses and site conditions. The site-specific remediation goals presented in this RAP constitute a site-specific Tier 3 analysis.

- As discussed in Section 6.7.2, the State of California (OEHHA, 1994) has adopted 10^{-5} as the "no significant risk" level for protecting persons from exposure to chemicals in consumer products and commercial establishments under Proposition 65. While this State statute and associated regulations are not ARARs for site remediation as noted in Section 6.7.2, the statutory history and regulatory process for application of Proposition 65 in California provide support for the local community's general acceptance of a cumulative cancer risk target of 10^{-5} and suggest that support and acceptance of such a target are appropriate as a component of all remedies selected for the OARB in this RAP.

In summary, given the precedents set by the community's acceptance of the City of Oakland ULR Program and Proposition 65, consideration of the acceptable risk range of 10^{-6} to 10^{-4} established in the NCP and related U.S. EPA guidance, and evaluation of the 10^{-6} point of departure typically utilized by DTSC for evaluation of remedial alternatives, this RAP establishes media-specific remediation goals for potential carcinogens as elements of all remedies for RAP sites and RMP locations on OARB as follow:

- A maximum allowable 10^{-6} risk level for <u>individual</u> carcinogenic COCs at the OARB property subject to this RAP, and

- When more than ten carcinogenic COCs are present at concentrations exceeding the remediation goals in Table 7-11, the overarching RAO is the <u>cumulative</u> target risk level of 10^{-5} for carcinogenic COCs applicable at each RAP site and RMP location identified at OARB.

Calculations of numerical risk-based remediation goals reflecting these risk target levels for the identified potentially complete exposure scenarios for planned reuse of the OARB are described in Section 7.3.4. Protocols for determining compliance with cumulative risk-based remediation goals are summarized in Section 7.5.

7.3.3.3 Lead Target Risk Level

Ingested or inhaled lead is distributed primarily to the blood, soft tissue (e.g., bone marrow, liver, and brain), and mineralizing tissue (e.g., bones and teeth) of the body. Lead interferes with normal cell function and with a number of physiologic processes, including damage to the central nervous system, inhibition of the body's ability to make hemoglobin, disruption of the endocrine system that may lead to impaired tooth and bone development, and damage to the kidneys (California Department of Health Services, 1997). ASTDR also indicates that lead readily crosses the placenta. According to ATSDR (1995a), lead not only affects the viability of the fetus, but development as well. Development consequences of prenatal exposure to low levels of lead include reduced birth weight and premature birth. Reports have indicated lead to be a teratogen and carcinogen in animals. However, studies in humans have failed to show a relationship between lead exposure concentrations and congenital malformations, and the association of lead levels and cancer observed in humans remains uncertain (ATSDR, 1995). Federal and state health agencies have focused on low-level environmental lead exposures where the primary health effect to be avoided is impaired learning or cognitive capacity in exposed children or adults.

Blood lead concentration is an integrated measure of internal dose resulting from the total exposure of releases of lead at a site and naturally occurring concentrations of lead in the environment and foods consumed. DTSC (1996) has established that the concentration of concern for lead in blood is 10 µg/dl at the 99th percentile (i.e., a one percent chance that blood lead concentrations will be greater than 10 µg/dl) for potentially exposed populations. The 99th percentile is believed to be protective because it establishes an upper bound level for lead exposure that is akin to U.S. EPA's reasonable maximum exposure ("RME") approach (U.S. EPA, 1989d). Determination of a remediation goal for lead in soil for potentially exposed commercial and industrial workers is discussed in Section 7.3.4.3.

7.3.4 Risk-Based Remediation Goal Calculations

Remediation goals were calculated for COCs using hazard and risk equations based on those presented in U.S. EPA (2000a, 1991a, 1989d), DTSC (1996), and City of Oakland (2000) guidance documents or models, as modified by discussion with the DTSC HERD staff regarding appropriate input parameters and default values. For example, inhalation rates are assumed to be 20 m^3 per workday for active work (construction, outdoor industrial, maintenance) and 10 m^3 per workday for less active work (indoor commercial) with no allowance for apportionment over a 9 hour work day

out of a possible 24-hour day. The remediation goal for lead was determined separately because of the different toxicological behavior of lead.

7.3.4.1 Groundwater Risk-Based Remediation Goals for Volatile COCs

Groundwater remediation goals to protect against vapor intrusion were derived using the U.S. EPA (2000a) "GW-ADV" version of the Johnson and Ettinger vapor intrusion computer model ("J&E Model"). The "GW-ADV" version is the Tier 2 model which allows the user to input site-specific parameters into the model (e.g., building dimensions, air exchange rate, crack radius), as opposed to relying on default parameters that may, or may not be appropriate. The screening level version of the J&E Model, "GW-SCREEN", is not appropriate for the OARB because it assumes a residential scenario without the ability to modify the inputs to the model (e.g. air exchange rate). The "GW-ADV" and "GW-SCREEN" versions of the J&E Model yield the same numerical results when the default inputs are the same.

Computer modeling of COC volatilization was conducted for those compounds detected in soil or groundwater at the OARB that met the U.S. EPA Region IX (2000b) definition of a volatile compound (see Section 7.3.2.1). All the California-specific toxicity factors available from OEHHA were inserted into the spreadsheet and utilized in the J&E Model runs for this RAP. Sample computer printouts and input parameters from the Johnson and Ettinger model runs are included as Appendix B.

7.3.4.2 Soil Risk-Based Remediation Goals for COCs Other Than Lead

Consistent with U.S. EPA (1991a, 1989d), DTSC (1999, 1996), and City of Oakland ULR program (2000), soil remediation goals based on non-carcinogenic effects ("RG_{nc}") were calculated using the following equation:

Equation 7-1 Non-carcinogen Soil Remediation Goal

$$RG_{nc} = \frac{RfD \times \text{Target HI of 1}}{(\text{Ingestion} + \text{Dermal} + \text{Inhalation})}$$

Soil remediation goals based on carcinogenic effects ("RG_c") were calculated using the following equation:

Equation 7-2 Carcinogen Soil Remediation Goal

$$RG_c = \frac{\text{Target Risk Level of } 10^{-6}}{SF \times (\text{Ingestion} + \text{Dermal} + \text{Inhalation})}$$

Ingestion, Dermal (i.e., direct contact), and Inhalation terms are estimates of exposure that may result from swallowing, absorbing COCs through the skin of an adult, and inhaling particulates and volatilized COCs. Exposure to COCs for various potentially exposed populations at the OARB were estimated by use of the equations listed below:

Equation 7-3 Soil Remediation Goal Ingestion Term

$$\text{Ingestion} = \frac{IR_{soil} \times FI \times EF \times ED \times 10^{-6}\ kg/mg}{BW \times AT}$$

Equation 7-4 Soil Remediation Goal Dermal Term

$$\text{Dermal} = \frac{SA \times AF \times ABS \times EF \times ED \times 10^{-6}\ kg/mg}{BW \times AT}$$

Equation 7-5 Soil Remediation Goal Inhalation Term

$$\text{Inhalation} = \frac{IR_{air} \times EF \times ED \times (1/VF + 1/PEF)}{BW \times AT}$$

Definitions of the exposure parameters within the equations are presented in Table 7-1. The above equations are generic and for illustration purposes. They do not indicate the different reference doses for different exposure routes or different cancer slope factors for different exposure routes, which were utilized in the calculations for this RAP. Where available, the route-specific reference doses and slope factors were utilized in these calculations and are tabulated in Tables 7-1 and 7-2. Where route-to-route extrapolations were performed, they are noted in the tables.

Soil remediation goals to protect against vapor intrusion were derived using the U.S. EPA (2000a) "SL-ADV" version of the J&E Model. Also available from the U.S. EPA is a screening level version of the model, "SL-SCREEN". The "SL-ADV" version was used as opposed to the "SL-SCREEN" version primarily because the "SL-SCREEN" version of the J&E model assumes an infinite soil source (i.e., the depth below grade to the bottom of the contamination is unknown). This assumption is not appropriate for OARB where potential soil sources are finite and limited in depth by the groundwater table at approximately 5 feet bgs. Additionally, the "SL-ADV" version of the model allows the user flexibility to input site-specific parameters into the model (e.g., building dimensions, air exchange rate, crack radius), as opposed to relying on default parameters that may, or may not be appropriate. The "SL-ADV" and "SL-SCREEN" versions of the J&E Model yield the same numerical results if the same input parameters are used and the depth below grade to the bottom of contamination is unknown.

7.3.4.3 Soil Risk-Based Remediation Goals for Lead

Potential lead remediation goals for individuals that may contact lead-impacted soil at the OARB (i.e., earthwork construction workers and maintenance personnel) were calculated using the DTSC Lead Spread Version 7.0 computer model. A remediation goal was calculated such that the lead concentration in the blood of these potentially exposed individuals was less than 10 μg/dl at the 99th percentile. The goal takes into account the potential intake of lead from releases at RAP sites and RMP locations, and lead naturally occurring in air, food, tap water, and soil, otherwise assumed to be typical human exposure to lead.

As provided in LeadSpread Version 7.0, DTSC default factors of 0.028 μg/m^3 and 1.1 kg food/day (at 3.1 μg lead/kg food) were used to account for lead naturally occurring in air and food, respectively, for adults. The concentration of lead in tap water was established as 15 μg/L. A value of 15 μg/L is the DTSC default factor, which is based on the federal action level for lead in municipal drinking water supply. Given the commercial and industrial uses planned for the OARB, the dietary source of lead assumes that no produce will be grown at impacted RAP sites or RMP locations. The lead remediation goals were calculated assuming an adult occupational worker exposure frequency of 5 days per week, as specified by DTSC (1996). Exposures of earthwork construction workers and maintenance personnel to ambient concentrations of lead in air, water, and food were assumed to be equivalent DTSC default factors. Copies of examples of computer spreadsheets used to calculate potential remedial goals for lead in soil are included as part of Appendix B.

These calculations indicated that lead concentrations of 3,500 mg/kg and 77,000 mg/kg in soil at the OARB potentially cause blood lead to increase to 10 µg/dl in earthwork construction workers and maintenance personnel, respectively, based upon the values of exposure parameters and frequencies assumed in the RAP.

Although calculations in LeadSpread model resulted in an allowable concentration of 3,500 mg/kg, DTSC believes that recent studies have indicated that lead exposure routes may exist in addition to those considered in the current model, e.g., fetal blood lead concentrations in women exposed to lead contaminated soils (EPA, 1996d). DTSC believes that with respect to lead in soil at the OARB, further conservatism in the selection of a health protective goal is appropriate. A mean residual concentration of 750 mg/kg at any given project site is, therefore, identified as the remediation goal for lead in soil at the OARB.

7.3.5 Input Parameters

Input parameters used in calculating risk-based remediation goals for the complete exposure pathways at OARB locations as illustrated on Figure 7-1 are discussed below.

7.3.5.1 Human Health Toxicity Values

Following the hierarchy established in DTSC's Preliminary Endangerment Assessment ("PEA") Guidance Manual, toxicity values used to calculate human health PRGs were obtained from the following references in the order listed:

- Carcinogenic slope factors were obtained from the OEHHA website entitled *California Cancer Potency Factors*, dated March 2001 (OEHHA, 2001).
- U.S. EPA's computerized Integrated Risk Information System ("IRIS").
- U.S. EPA's Health Effects Assessment Summary Tables ("HEAST"), dated July 1997.
- U.S. EPA's National Center for Environmental Assessment ("NCEA"), Draft Risk Assessment Issue Papers for individual chemicals.

OEHHA's technical documents and website represent the agency's most current stance on non-carcinogenic and carcinogenic toxicity values for risk assessments in California. U.S. EPA maintains the IRIS computerized database. Toxicity values on IRIS have undergone review and verification by U.S. EPA program offices prior to publication.

Toxicity values were obtained from HEAST if none were available from OEHHA or IRIS. HEAST is not updated as regularly as IRIS and may contain interim toxicity values. NCEA was the final information source consulted. Toxicity values obtained from NCEA have not been verified by U.S. EPA and are considered provisional. Non-carcinogenic and carcinogenic toxicity information for the identified COCs, including the source of the information, is shown on Tables 7-1 and 7-2, respectively. If no toxicity value was available for one of the exposure routes for a particular chemical (shown as a blank on Tables 7-1 or 7-2), the toxicity value from the other exposure route was used in the calculations (i.e., "route-to-route extrapolation").

Toxicity values for surrogate compounds were used for most of the chemicals for which no published toxicity values were available from the above sources. No appropriate surrogate compounds were available for some COCs (e.g., polychlorinated biphenyls). For such chemicals, non-carcinogenic human health remediation goals could not be calculated and are noted as such in the tables.

7.3.5.2 Human Health Exposure Parameters

In accordance with DTSC PEA Guidance Manual, the same exposure parameter values were used to calculate non-carcinogenic and carcinogenic PRGs except for the averaging time. Averaging time is 70 year for carcinogenic risk, but averaging time is set equal to the exposure duration for non-carcinogenic hazards, in accordance with DTSC (1999) guidance.

As shown in Table 7-3, where available, exposure parameters are default factors obtained from U.S. EPA, DTSC, or City of Oakland guidance documents or are calculated based on published values for the potentially exposed populations identified at the OARB (see Figure 7-1). The exposure frequency and duration for earthwork construction workers and maintenance personnel while excavating soil at the OARB locations are the only parameters where default factors do not exist and professional judgment was used to estimate values. Exposure frequency is the number of days per year that an individual is likely to engage in trenching or other activities that involve disturbance and contact with soil (e.g., foundation construction, landscape installation, and utility installation and repairs). The exposure frequency for earthwork is assumed to be 250 days per year for earthwork construction workers and 12 days per year for future maintenance personnel. Non-earthwork exposure frequency is assumed to be 238 days per year for maintenance personnel. Exposure duration is the length of time in years during which an individual performs earthwork. The exposure duration is assumed to be 1 year for earthwork construction workers and 25 years for maintenance personnel.

The U.S. EPA default soil ingestion rate for earthwork construction workers is 480 mg/day, which is often used as an estimated reasonable maximum exposure for daily soil ingestion by unprotected construction workers (U.S. EPA, 1997d; 1991h). This default soil ingestion rate represents a maximum likely exposure scenario in which a hypothetical coating of soil on the fingers and thumbs of both hands is ingested twice per day by hand-to-mouth contact (Hawley, 1985). Other estimates of soil ingestion rates exist for workers; for example, DTSC (1996) recommends a soil ingestion rate of 100 mg/day for an adult agricultural exposure scenario. At OARB, the RMP requires earthwork construction workers and maintenance workers to be informed on site conditions and to follow site-specific health and safety procedures that will limit their soil ingestion (e.g., by directing them to minimize direct contact with potentially contaminated soil and to wash hands before eating or smoking). Thus, a soil ingestion rate of 100 mg/day (equivalent to the agricultural worker) better represents a site-specific reasonable maximum exposure for future earthwork construction workers and for maintenance workers when the latter are digging below covering materials at OARB, who will follow site-specific health and safety plans developed in accordance with protocols specified in the RMP.

7.3.5.3 Physical Parameters

Physical parameters, such as soil properties, depth to groundwater, climatic parameters, and building parameters used to calculate risk based remediation goals are shown in Table 7-4. Physical parameters were obtained from site specific information or default values obtained from U.S. EPA (1989d; 2000a), DTSC (1999), or the City of Oakland ULR Program (2000).

Chemical parameters were obtained from several sources. If available, Henry Law constants were obtained from Gossett (1987). Secondary sources for Henry Law constants included Mackay and Shiu (1981) and Montgomery (2000). Organic carbon partition coefficients, aqueous solubilities, and diffusion coefficients were obtained from Montgomery (2000).

7.3.6 Compilation of Risk-based Remediation Goals

Tables 7-5, 7-6, 7-7, and 7-8 summarize the calculated non-carcinogenic and carcinogenic soil remediation goals for earthwork construction workers, indoor commercial workers, outdoor industrial workers, and maintenance personnel, respectively, at the OARB. Based on this evaluation (see Section 7.3.4.3), a remediation goal for lead in soil of 750 mg/kg is determined to be applicable to OARB locations subject to this RAP. Table 7-9 summarizes the groundwater remediation goals for the

indoor commercial worker using the U.S. EPA Johnson and Ettinger vapor intrusion computer model.

7.4 SUMMARY OF REMEDIATION GOALS

Selected cleanup levels for most chemicals are risk-based remediation goals that are the lowest values of RG_{nc} and RG_c for each COC that protect all potentially exposed populations consistent with pathways shown on Figure 7-1. However, chemical-specific ARARs or TBCs are adopted as remediation goals for some COCs. For example, the Army's Fuel Storage Tank Sites Cleanup Levels (IT, 2000n) have been adopted as the site-specific remediation goals for petroleum hydrocarbons in soil and groundwater at the OARB.

ARARs or TBCs were also selected if the values are more stringent than the calculated human health risk-based remediation goals. As shown in Table 7-10, the lowest risk-based remediation goal for each COC was compared with the RWQCB Soil Leaching Screening Level (2001a) intended to protect groundwater that is not potential drinking water supply. The RWQCB Soil Leaching Screening Level was adopted as the OARB soil cleanup level if it was less than the calculated risk-based remediation goal. Remediation goals based upon RWQCB Soil Leaching Screening Levels may be amended by additional site-specific evaluation if the need arises in the future. Amendment of remediation goals will be conducted only with DTSC or RWQCB consent.

As discussed in Section 7.3.2.2, no numerical cleanup levels have been calculated for metals and other non-volatile COCs in groundwater because since ingestion, dermal contact, and inhalation of COCs in groundwater by earthwork construction workers and maintenance personnel are relatively insignificant (see Appendix C).

Available data do not indicate that COCs in groundwater at the OARB are migrating in the shallow water-bearing zone to San Francisco Bay. However, it is possible that groundwater migrates to San Francisco Bay through the storm drains. Storm drain piping at the OARB is documented to have breaks and cracks and contamination has been detected in marine sediment samples obtained adjacent to storm drain outfalls. Storm drain piping is often situated in the saturated zone and groundwater may enter the cracked or otherwise breached storm drain piping. No significant human exposures associated with storm drain conditions are occurring. Environmental impairment related to damaged storm drains will be addressed through implementation of remedial actions described in Section 10.2.2.7.

Remedial actions implemented at each RAP site or RMP location will meet individual remediation goals for soil and groundwater listed in Table 7-11. The individual remediation goals in Table 7-11 represent the maximum allowable concentrations for the respective COCs. These remediation goals will not be increased to allocate amongst the residual COCs to meet the overarching cumulative risk of 10^{-5}. However, these remediation goals can be adjusted downward, as need, if the total cancer risk levels exceeds 10^{-5} or the total hazard index exceeds 1. Cumulative HIs and carcinogenic risks associated with residual COCs at each RAP site or RMP location will be calculated as described in Section 7.5. RAOs are achieved when residual COCs in soil and groundwater are no greater than a cumulative HI of 1 or a cumulative carcinogenic risk of 10^{-5} for each potentially exposed population.

7.5 PROTOCOLS FOR DETERMINING COMPLIANCE WITH CUMULATIVE RISK-BASED REMEDIATION GOALS

Cumulative HIs and carcinogenic risks will be calculated for each RAP site or RMP location after remedial actions have been completed to ensure that residual COCs in soil and groundwater are not present at concentrations that pose an unacceptable potential human health hazard. Cumulative HIs and carcinogenic risks will be calculated using the remediation goals for potentially exposed population summarized in Tables 7-5 through 7-9 and representative concentrations ("RCs") of all COCs detected in soil and groundwater at a RAP site or RMP location. RCs will be based upon appropriate arithmetic or geometric mean values, the 95 percent upper confidence limits ("95% UCL") on the appropriate means, or the maximum COC concentrations detected at a RAP site or RMP location. When there is an insufficient number of data points, the maximum detected COC concentrations can be used as the RCs.

7.5.1 Calculation of Cumulative HI

Cumulative HIs will be calculated for the four potentially exposed populations identified in Section 7.3.1. These populations consist of: (1) earthwork construction worker, (2) indoor commercial worker, (3) outdoor industrial worker, and (4) maintenance personnel. RAOs based upon non-carcinogen human health effects are achieved when the cumulative HI for each potentially exposed population is calculated to be less than 1. Cumulative HIs will be calculated using the following equation:

Equation 7-6 Cumulative Non-carcinogenic Risk

$$\text{Cumulative HI} = \left(\frac{RC_1}{RG_{nc2}}\right) + \left(\frac{RC_2}{RG_{nc2}}\right) + \ldots \left(\frac{RC_N}{RG_{ncN}}\right)$$

where:

$RC_{1,2\ldots N}$ = representative concentration of each COC at RAP site or RMP location

$RG_{nc1,2\ldots N}$ = non-carcinogenic remediation goal for each COC summarized in Tables 7-5 through 7-9 for the potentially exposed population under consideration

Consideration of potential impacts to particular organs, if judged appropriate and with written DTSC approval, can be accomplished using information such as that available in Table L of the RWQCB RBSL document (RWQCB, 2001a, as updated). The above equation would be used only for those COCs judged to have comparable target organs; more than one cumulative HI could be calculated with different groups of potential health effects if appropriate. RAOs based upon non-carcinogen human health effects are achieved when the cumulative HI for each potential grouping of target organs or health effects is calculated to be less than 1.

7.5.2 Calculation of Cumulative Carcinogenic Risk

Cumulative carcinogenic risks will be calculated for the four potentially exposed populations identified in Section 7.3.1. RAOs based upon carcinogenic health effects are achieved when the cumulative carcinogenic risk for each potentially exposed population is calculated to be less than 10^{-5}. Cumulative carcinogenic risks will be calculated using the following equation:

Equation 7-7 Cumulative Carcinogenic Risk

$$\text{Cumulative Carcinogenic Risk} = \left(\frac{RC_1}{RG_{c1}} \times 10^{-6}\right) + \left(\frac{RC_2}{RG_{c2}} \times 10^{-6}\right) + \ldots \left(\frac{RC_N}{RG_{cN}} \times 10^{-6}\right)$$

where:

$RC_{1,2\ldots N}$ = representative concentration of each COC at RAP site or RMP location

$RG_{c1,2\ldots N}$ = carcinogenic remediation goal for each COC summarized in Tables 7-5 through 7-9 for the potentially exposed population under consideration

8. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Identifying and screening potentially suitable technologies is the initial step in assembling appropriate remedies that achieve the RAOs established in Section 7, comply with ARARs, and satisfy other evaluation criteria established by U.S. EPA and the State of California. Technologies that pass the screening process are developed into remedial alternatives. The remedial alternatives are themselves screened and the alternatives that are retained undergo detailed analysis. The results of the detailed analysis determine the remedial alternatives that are recommended for implementation. Section 8 describes the identification and screening of technologies. Section 9 summarizes the development and screening of remedial alternatives. Section 10 presents the detailed analysis of alternatives.

8.1 PRINCIPAL THREAT AND LOW-LEVEL THREAT WASTES

To facilitate the identification and screening of technologies, U.S. EPA (1991b) has developed guidelines to communicate the types of remedies it generally anticipates to find appropriate for different source materials. U.S. EPA (1997d) defines source material as:

> ...material that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, to surface water, to air, or acts as a source for direct exposure.

Source material is divided into principal threat waste and low-level threat waste. The definitions of these wastes are as follows:

- **Principal Threat Waste:** Source material that is considered to be highly toxic or extremely mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. Principal threat waste includes NAPL, extremely mobile liquids (e.g., solvents), or materials having high concentrations of toxic compounds. Although no "threshold level" of toxicity has been established for definition of a principal threat waste, U.S. EPA (1991b) indicates for conditions where toxicity and mobility of source material combine to pose a potential risk of 10^{-3} or greater, treatment alternatives generally should be evaluated.

- **Low-level Threat Waste:** Source material that can be reliably contained and that would pose only a low risk in the event of exposure. Low-level threat waste is source material that exhibits low toxicity, limited mobility in the environment, or has COC concentrations near health-based levels.

As discussed in Section 4.4, except for the former ORP / Building 1 area, source material encountered at the OARB can be characterized as low-level threat waste. The majority of the RMP locations at the OARB consist of former tanks, washracks, or oil/water separators that resulted in the known or suspected release of petroleum hydrocarbons to soil although solvents and other VOCs, and metals have also been detected as well. The detected petroleum hydrocarbons are higher molecular weight compounds. These petroleum hydrocarbons are likely to be weathered residuals that are relatively immobile and generally do not contain appreciable amounts of other contaminants, such as VOCs, PAHs, or metals that would constitute a human health risk. No potential NAPL or heavily contaminated soil that may leach COCs and serve as ongoing contaminant sources have been identified at the OARB. Significant migration of COCs in groundwater has not been documented anywhere on the OARB. The extent of impacted groundwater appears to be limited to portions of the shallow water-bearing zone that are entirely within the property boundary of the OARB. Potential migration of COCs in groundwater to San Francisco Bay through the storm drains is discussed in Section 3.5.2. The former ORP / Building 1 area is unique in that the tarry residue constitutes the only principal threat waste known to exist at the OARB. The tarry residue is considered to be a principal threat waste because it can be very acidic. A pH of 1 has been measured for some samples of this material. In addition, lead, PAHs, PCDDs, and PCDFs have been detected in the tarry residue at concentrations significantly greater than site-specific remediation goals.

8.2 IDENTIFICATION AND SCREENING OF GENERAL RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

The NCP at 40 CFR §300.430(a)(1)(iii)(A) states that "U.S. EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds and highly mobile materials." On the basis of this expectation, treatment appears to be an appropriate remedy for the tarry residue at former ORP / Building 1 area.

Contaminated soil at the other identified RAP sites and RMP locations can be considered low-level threat wastes. The NCP at 40 CFR §300.430(a)(1)(iii)(B) states that

"U.S. EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable." However, the long-term effectiveness of such remedies must be enforced through the use of institutional controls that ensure, among other things, that assumptions regarding the integrity of cover and exposure duration stay relevant. While use of cover systems to address low-level threat wastes is likely to satisfy CERCLA statutory requirements, redevelopment of the OARB may be better served by abating impacted soil and groundwater under certain circumstances and concerns regarding the long-term effectiveness of cover systems. As a result, OBRA anticipates that containment will be used in combination with more active measures to address low-level threat wastes at various RAP sites and RMP locations at the OARB.

Tables 8-1 and 8-2 summarize the screening of general response actions for impacted soil and groundwater at RAP sites and RMP locations at the OARB, respectively. U.S. EPA (1988a) considers general response actions to be those actions that will satisfy RAOs established for a site. General response actions are divided into remedial technologies, which themselves are divided into process options. Remedial technologies refer to general categories of technologies, such as capping, subsurface barriers, or extraction. Process options refer to specific processes within each category of remedial technology. For example, extraction remedial technology would include the process options of using wells or trenches to remove groundwater from the subsurface. As indicated in Tables 8-1 and 8-2, several broad types of remedial technologies may be identified for each general response action, and numerous process options may exist for each category of remedial technology.

In accordance with U.S. EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*, OBRA has eliminated for current implementation those general response actions, remedial technologies, and process options that do not achieve the criterion of technical implementability. The physical conditions, types and concentrations of COCs in soil and groundwater, and intended land reuse were reviewed to determine which approaches cannot be effectively implemented at the OARB under known current conditions. The results of screening for general response actions, remedial technologies, and process options are discussed in Sections 8.2.1 through 8.2.13.

8.2.1 No Action

The NCP at 40 CFR §300.430(e)(6) requires that the "no action" alternative be evaluated as a baseline for comparison of other alternatives developed. The no action alternative may be appropriate for selection under certain circumstances. U.S. EPA (1991g) states the following regarding the need to implement remedial actions at a site:

If the baseline risk assessment and the comparison of exposure concentrations to chemical-specific standards indicates that there is no unacceptable risk to human health or the environment and that no remedial action is warranted, then the CERCLA Section 121 cleanup standards for selection of a Superfund remedy, including the requirement to meet applicable or relevant and appropriate requirements (ARARs), are not triggered.

The no action alternative is viable for RAP sites and RMP locations and basewide environmental issues where COCs in soil and water are less than screening levels for unrestricted use, which are discussed in Section 5. This general response action is **retained** for further consideration.

8.2.2 Institutional Controls

Institutional controls are non-engineering measures designed to limit exposure to hazardous substances left in-place or to ensure the effectiveness of the chosen remedy. Institutional controls that may be applicable to RAP sites and RMP locations and basewide environmental issues consist of land and groundwater use restrictions, and a requirement to comply with the RMP.

DTSC requires the City to enter into a land use covenant to ensure that the State of California will have authority to implement, monitor, and enforce protective restrictions. The land use covenant shall be recorded with the Alameda County Assessor's Office. The land use covenant will be binding on the City and subsequent property owners and will remain in effect until it is formally removed or modified pursuant to the procedures contained in the land use covenant. The land use covenant shall clearly specify the restrictions and prohibitions identified below.

- Sensitive land uses, including, but not limited to, residential housing, schools, day-care facilities, hospitals and hospices are restricted and prohibited. DTSC may issue waivers to allow sensitive uses at sites where DTSC deems appropriate. Waivers currently under consideration for the interim uses are described in Appendix D. The waivers under consideration would be in effect for five years after conveyance.

- The construction of groundwater wells and extraction of groundwater from new and existing wells for all purposes are restricted and prohibited. DTSC may issue

written approval for environmental investigation, monitoring, and remediation. Construction dewatering activities shall be conducted pursuant to the RMP.

- The RMP provisions, which include provisions for soil and groundwater management, maintenance of existing cover or construction of new cover, mitigation measures during earthwork, management of below grade structures, etc., shall be followed.

- Submission of annual certifications to DTSC attesting the compliance of institutional controls are required.

The Amended Reuse Plan states that the OARB will be redeveloped for commercial and industrial purposes. The remedial actions described in this RAP are intended to protect human health and the environment based upon these reasonably anticipated land uses. The remedial actions may not be sufficiently protective if the OARB was to be redeveloped for other uses such as residential housing. Accordingly, institutional controls are an integral component of all remedial actions to ensure that the future land uses remain compatible with the remedial actions that are implemented at the OARB. Institutional controls include land use restrictions, which can also be referred to as deed restrictions. Although the term deed restrictions commonly appears in remedial action plans and other related documents, it is not a traditional real property term and does not have a precise legal meaning (U.S. EPA, 1999c). Deed restrictions and land use restrictions are catchall phrases for legal controls such as easements, restrictive covenants, and zoning ordinances. These controls either prohibit certain kinds of site uses or notify potential owners or tenants of the presence of hazardous substances remaining on-site at concentrations that are not protective of all uses. For such alternatives to be protective, U.S. EPA (1995d) states:

> ...it is essential that the alternative include components that will ensure that it remain protective. In particular, institutional controls will generally have to be included in the alternative to prevent an unanticipated change in land use that could result in unacceptable exposures to residual contamination, or, at a minimum, alert future users to the residual risks and monitor for any change in site use.

U.S. EPA expects that institutional controls typically will be used in conjunction with engineering controls. This expectation is made clear in the NCP. At 40 CFR §300.430(a)(1)(iii)(D), U.S. EPA states the following:

> The use of institutional controls shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of ground waters to their beneficial uses) as the sole remedy unless such active measures are determined not be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of the remedy.

Institutional controls are more effective if they are layered or implemented in series (U.S. EPA, 2000c). Layering institutional controls means using different types of institutional controls at the same time to enhance the protectiveness of remedial actions. Implementing institutional controls in series means using institutional controls at different points in the remediation process to ensure the short- and long-term protection of human health and the environment. The City anticipates that institutional controls implemented as part of remedial actions under the RAP will be both layered and implemented in series. For example, a set of covenants will be established during the interim leasing period prior to redevelopment of the OARB. These covenants will be amended after the OARB has been redeveloped and remedial actions have been performed to reflect changed land use and environmental conditions. Layering of institutional controls will be accomplished through enforcement of covenants, groundwater use restrictions, provisions in the consent agreement to be executed with DTSC, and the specialized building permit requirements instituted through the City of Oakland ULR program.

The City of Oakland ULR program has established a computerized system that ensures land use restrictions are enforced so properties with residual contamination are not redeveloped for unintended uses unless additional remediation is performed. The City's computerized system tracks permits from filing to issuance and provides the user with a permitting and inspection history. The City of Oakland Community and Economic Development Agency ("CEDA") maintains the system. CEDA is responsible for operations related to development, inspection, and enforcement of zoning, planning, building, and housing codes within the City of Oakland. The computerized system allows permits to be properly routed and held, if necessary. The purpose of these procedures is to provide the appropriate City of Oakland staff with the opportunity to review permit applications for work that may either conflict with land use restrictions or trigger further remediation under an approved remedial action plan.

The City does not consider land use restrictions by themselves to be appropriate for sites where source material may remain in-place. However, as discussed in Section 8.2.3, land use restrictions in combination with monitoring may be suitable for sites where no source

material exists in soil and COCs in groundwater are therefore likely to decrease due to natural attenuation. Institutional controls are **retained** for further consideration.

8.2.3 Monitored Natural Attenuation

Monitoring is an important component of remedial actions where residual COCs may be left above applicable remediation goals in soil or groundwater. Groundwater sampling, or monitored natural attenuation ("MNA"), can be an appropriate groundwater remedial action at specific locations. However, monitoring alone is not a remedial alternative. Monitoring is an evaluation tool or data gathering activity to demonstrate the effectiveness of the selected remedies over time. For sites where land use restrictions will be imposed, monitoring is essential to confirm that land use restrictions are performing as intended. For example, if land use restrictions prohibit construction of potable water supply wells, routine inspections must be performed to ensure that construction of such wells is not occurring. Similarly, if a cover system is placed over a hazardous substance release site, monitoring is needed to assess if digging beneath the cover is taking place and, if so, whether it is being conducted in such a manner that minimizes potential risk to human health and the environment. U.S. EPA (2000h) states that the details concerning monitoring of land use restrictions should be included in the cleanup order or a document referenced in the order, such as an Operation and Maintenance Plan. As discussed in Section 4.4.2.2, this plan is referred to as a RMP for the OARB. The RMP is included as Appendix E to this RAP.

Monitoring may also entail ongoing soil or groundwater sampling to assess the impacts on environmental conditions of residual COCs at RAP sites and RMP locations at the OARB, such as may be required by RWQCB for some period of time at former petroleum tank locations. Routine groundwater sampling, in particular, is anticipated to be a component of preferred remedial actions for several RAP sites and RMP locations, such as benzene/MTBE-impacted groundwater near Building 828. After addressing source material in soil at this and other similar locations, MNA, may be an appropriate groundwater remedial action. U.S. EPA (1999d) defines MNA as the following:

> ...the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and

groundwater. These *in-situ* processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

U.S. EPA (1999d) stresses that source control and long-term performance monitoring will be fundamental components of any MNA remedy. MNA is an appropriate remedial action for the OARB where its use protects human health and the environment, and where it is capable of achieving RAOs within a time frame that is reasonable compared to other alternatives. Monitored natural attenuation is **retained** for further consideration.

8.2.4 Containment

Containment refers to the use of capping technologies or engineered cover systems to minimize contact of wastes and COCs in soil by humans and ecological receptors. Containment remedies are often compatible with anticipated future land uses. Properties with cover systems have been transformed into wildlife enhancement areas, recreational facilities, and commercial developments (U.S. EPA, 1999b). Containment is a "presumptive remedy" for soil with metals that pose a low-level threat (U.S. EPA, 1999a).[21]

Depending upon the properties of COCs in soil being contained, the cover system may have to be designed to reduce surface water infiltration, control VOC emissions, provide stability, or improve aesthetics. Regardless of the type of cover system selected, institutional controls and ongoing maintenance activities are likely to be included as part of the containment remedy to ensure its long-term protectiveness. A RMP that specifies inspection frequencies, repair methods, and other protocols to protect the cover will be developed as a component of the RAP.

8.2.4.1 Permeable Cover Systems

Permeable cover systems are not designed to restrict the infiltration of surface water. Permeable covers may consist of clean soil, building slabs, asphalt roadways, and

[21] Presumptive remedies are preferred response actions or technologies for sites with similar characteristics. U.S. EPA identifies presumptive remedies based upon information acquired from evaluating and cleaning up sites under Superfund. A primary reason for U.S. EPA establishing presumptive remedies is to streamline remedy selection by narrowing the universe of technologies and alternatives that must be considered. U.S. EPA (1993b) also believes that presumptive remedies will produce the added benefit of promoting consistency in remedy selection and improving the predictability of the remedy selection process for communities and potentially responsible parties. A simpler and less technical discussion of presumptive remedies can be found in U.S. EPA's (1997a) *A Citizen's Guide to Understanding Presumptive Remedies.*

concrete pavement to be constructed as part of redevelopment. Use of permeable covers is appropriate for most RAP sites, RMP locations, and basewide issues at the OARB because COCs consist primarily of high molecular weight petroleum hydrocarbons, metals, or other low mobility COCs that are not volatile and are not prone to leaching to groundwater. Permeable covers are **retained** for further consideration.

8.2.4.2 Low-Permeability Cover Systems

Low-permeability cover systems are designed to promote surface water drainage away from the cap and to minimize infiltration of water into the soil containing COCs. Low-permeability cover systems may also be used as a barrier against vapor intrusion.

Infiltration of surface water is not a significant concern at the OARB. Most COCs identified at the OARB sorb tightly to soil and are not generally considered to be mobile in the environment (e.g., high molecular weight petroleum hydrocarbons, PAHs, metals). VOCs and fractions of petroleum fuels (e.g., low molecular weight petroleum hydrocarbons and BTEX) that can leach from soil appear to have volatilized, degraded, or already migrated to groundwater to the extent possible at the OARB. Review of available analytical results indicates that concentrations of VOCs and fuel constituents at RAP sites and RMP locations with impacted groundwater are relatively stable or declining over time. Further, investigative findings demonstrate that the areas of impacted groundwater in the shallow water-bearing zone are limited. The largest area with VOC-impacted groundwater is near Building 99. This area is approximately 500 feet long and 500 feet across at its widest point but contains low VOC concentrations in groundwater as discussed in Section 4.4.3.4.

A cover system intended as a vapor barrier typically consists of a low-permeability geomembrane placed over a foundation layer, such as compacted sand or aggregate. The geomembranes can consist of sprayed elastomeric material (e.g., LIQUID BOOT®), or be constructed of high density polyethylene ("HDPE"), linear low density polyethylene ("LLDPE"), or polypropylene. HDPE is widely accepted by regulatory agencies. However, in certain cover applications, LLDPE and polypropylene may be advantageous due to their ability to accommodate larger strains induced by settlement. A low-permeability cover system might be incorporated into the design of new buildings at the OARB and could be augmented by sub-slab depressurization technology, which is discussed in Section 8.2.5.1.4. Low-permeability cover systems for use as vapor barriers are **retained** for further consideration.

8.2.5 In-situ Soil Treatment

In-situ soil treatment consists of remedial technologies that destroy COCs or reduce their toxicity or mobility without first having to excavate the wastes or affected soil. With these technologies, soil is treated in-place, which can minimize waste generation. In-situ soil treatment consists of physical / chemical, thermal, and biological remedial technologies.

8.2.5.1 In-situ Soil Treatment Using Physical / Chemical Technology

Soil flushing, immobilization, soil vapor extraction, sub-slab depressurization, and electrokinetics are the process options considered in this RAP that use physical / chemical technology for in-situ treatment of soil.

8.2.5.1.1 Soil Flushing

Soil flushing involves injecting an aqueous solution to remove COCs from the subsurface without first having to excavate the wastes or affected soil. COCs are liberated from or transformed in soil if they are soluble, create an emulsion, or react with the solution injected into the subsurface. After passing through the affected soil, the aqueous solution is collected by strategically placed extraction wells, and brought to the surface for disposal, recirculation, or on-site treatment and reinjection.

Complete recovery of the aqueous solution used to wash soil has been found to be extremely difficult. Substantial amounts of wastewater and slurry may be generated to remove COCs that are present in soil at relatively low concentrations. These residuals require treatment and disposal. Further, soil flushing is an emerging technology that has not been extensively applied to remove inorganic compounds such as metals from soil. Most soil flushing applications involve remediation of VOCs on a bench or pilot scale (Smith, et al, 1995). Under the NCP at 40 CFR §300.430(a)(1)(iii)(E), innovative technologies are to be considered as potential remedial actions when such technologies offer:

> ...the potential for comparable or superior treatment performance or implementability, fewer or less adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.

Soil flushing is an emerging physical / chemical process that has not been demonstrated for full-scale application. Soil flushing is **not retained** for further consideration because

other suitable and more reliable processes exist for removing or treating COCs detected in soil at the OARB.

8.2.5.1.2 Immobilization

Immobilization refers to mixing chemical reagents with wastes or COC-containing soil to change the toxicity, or physical or leaching characteristics of these materials through solidification and stabilization processes. Solidification entails physically locking COCs within a solidified matrix in the form of a crumbly soil-like mixture or a monolithic block. Stabilization converts COCs to a more immobile form, typically by chemical reaction. Immobilization is a presumptive remedy for soil with metals that pose a principal threat (U.S. EPA, 1999a).

A significant challenge for successfully accomplishing immobilization in-situ is uniform mixing of chemical reagents with the impacted soil (U.S. EPA, 1991c). Approaches used for in-situ mixing of chemical reagents include in-place mixing by conventional earth-moving equipment such as backhoes, draglines, or clamshell buckets, and injection grouting or vertical auger mixing. Injection grouting involves forcing a solution containing dissolved or suspended reagents under pressure into the subsurface. In vertical auger mixing, a system of augers is used to inject and mix reagents into the soil. Crane-mounted vertical augers loosen the soil and mix in reagents. In-situ immobilization with conventional earth-moving equipment is limited to near surface soil. Both shallow (10 to 20 feet bgs) and deep (up to 150 feet bgs) immobilization can be accomplished by vertical auger mixing, which is adapted from the construction industry (Smith, et al, 1995).

The former ORP / Building 1 area is the only RAP site or RMP location at the OARB that contains high concentrations of metals for which in-situ immobilization would be potentially applicable. However, verifying satisfactory mixing of reagents in the subsurface is often difficult. Given the heterogeneous nature of the tarry residue in which high lead concentrations and low pH are found, it may be difficult to stabilize the material. Even if the metals could be stabilized, the tarry residue will still contain elevated levels of PAHs, PCDDs, and PCDFs that may unacceptably restrict commercial and industrial reuse of the former ORP / Building 1 area.

No current application for in-situ immobilization has been identified for RAP sites or RMP locations at the OARB. Remedial alternatives incorporating this process option have not been assembled. Nevertheless, in-situ immobilization is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of this process option.

8.2.5.1.3 Soil Vapor Extraction

Soil vapor extraction ("SVE") is a process for removing VOCs from unsaturated soil. SVE generally does not address non-volatile chemicals, such as metals and higher molecular weight PAHs. SVE requires installing one or more vertical or horizontal extraction wells in the affected soil. A vacuum is applied to the wells to induce air flow through the soil and into the SVE well. VOCs volatilize as air moves through the soil. VOC-laden air is captured by the SVE extraction wells for off-gas treatment or discharge to the atmosphere. Common off-gas treatment systems include granular activated carbon ("GAC") adsorption, and thermal or catalytic oxidation.

For RAP sites or RMP locations with a mixture of VOCs and non-volatile contaminants, U.S. EPA (1996c) states that SVE should be considered only if it can be used in combination with other remedies. SVE is **retained** for possible future use in the event conditions at RAP sites or RMP locations at the OARB are found to warrant application of this process option. However, remedial alternatives incorporating this process option have not been assembled.

8.2.5.1.4 Sub-slab Depressurization

Sub-slab depressurization ("SSD") technology is based on the same principles as SVE. However, the design objective of SSD is not to remediate contaminated soil but to prevent soil gases from infiltrating into a building. An active SSD system is operated continuously to create a slight vacuum beneath the concrete foundation slab of the building. The induced vacuum beneath the building foundation slab overcomes the lower pressure that often exists inside a building thereby preventing soil gas from flowing into the building.

An active SSD system requires installation of vent piping in one or more central, or other appropriately selected locations in the aggregate layer beneath the foundation slab. The vent piping is connected to a small blower or wind-driven turbine to create the vacuum beneath the foundation slab. The vacuum beneath the building foundation must be sufficient to overcome the lower pressure inside the building. Soil gas withdrawn from the vent piping beneath the building is treated to remove VOCs and is subsequently discharged to the atmosphere. The discharge stack of the SSD treatment facility should be sufficiently far from the intakes of mechanical ventilation systems to avoid transferring treated soil gas into buildings. Applicable building codes should be consulted to determine the necessary clearance for mechanical ventilation system intakes.

U.S. EPA (1994a, 1993e) has long recognized the value of SSD in reducing airborne radon concentrations inside residences and commercial buildings. SSD has been adapted at numerous sites across the United States to mitigate VOC vapor intrusion risks. The Massachusetts Department of Environmental Protection (1995) states that "SSD systems are a proven, effective, and economical means for intercepting subsurface vapors that would otherwise infiltrate into a structure of concern. These systems have been successfully installed and operated in residential, commercial, and school buildings throughout Massachusetts." SSD systems would be used together with low-permeability covers as vapor barriers. Although the construction of SSD systems and vapor barriers would be incorporated into the design of new buildings at the OARB, such systems are considered elements of site-specific remedial actions in the RAP. SSD is **retained** for further consideration.

8.2.5.1.5 Electrokinetics

Electrokinetics has been proposed to remove metals and other COCs from soil and groundwater by applying an electric field in the subsurface. The process reportedly works by using a charged electric field to induce movement of ions, particulates, and water through soil (Hinchee et al, 1989). The electric field is applied through anodes and cathodes placed in the soil. Most metals form positively charged ions that migrate towards the negatively charged electrode, or cathode.

A conductive solution must be injected into unsaturated soil to act as a carrier for metals to the cathodes. Like soil flushing, this conductive solution must be recovered for treatment. For this reason, electrokinetics is considered most applicable to saturated soil with nearly static groundwater flow and moderate to low permeability. A low groundwater flow rate is required so that ionic diffusion rather than advective flow is the main transport mechanism. Water is required to provide a polar medium for flow of metal ions. Electrokinetics is less dependent on high soil permeability than soil flushing because electrokinetic separation occurs due to ionic migration rather than bulk fluid flow. Fine-grained soil, such as clay and silt, are reported to be a good medium for electrokinetics (U.S. EPA, 1992a). Heterogeneities or anomalies found at sites, such as building foundations, rubble, significant quantities of iron or iron oxides, large rocks, or gravel may reduce the efficiency of metal removal (Acar et al, 1995).

Electrokinetics is still in the development phase. Electrokinetics is **not retained** for further consideration because other suitable and more reliable processes exist for removing or treating COCs detected in soil at RAP sites or RMP locations at the OARB.

8.2.5.2 In-situ Soil Treatment Using Thermal Technology

Vitrification is the only process option considered in this RAP that uses thermal technology for in-situ treatment of soil. Vitrification converts affected soil into a stable glass or crystalline monolith. Vitrification is based on electric melter technology, and the principle of operation is joule heating, which occurs when an electrical current is passed through a region that behaves like a resistive element. Electric current is applied through an array of electrodes inserted vertically into the zone of affected soil. Because dry soil is not conductive, flaked graphite and glass frit is placed in a small trench between the electrodes to act as the starter path for the flow of electricity. Electricity in the starter path transfers heat that melts the soil. The soil becomes conductive once molten. The melt grows outward and downward as electricity is continually applied. Smith et al (1995) reports that soil has been treated to a maximum depth of approximately 20 feet bgs with this process.

Availability of equipment limits implementability of vitrification (U.S. EPA, 1999a). In addition, the process is expensive to implement with costs highly dependent upon local energy rates, and the characteristics of deposited wastes and soils with COCs. For these reasons, vitrification is **not retained** for further consideration.

8.2.5.3 In-situ Soil Treatment Using Biological Technology

Phytoremediation and bioremediation are the process options considered in this RAP that use biological technology for in-situ treatment of soil.

8.2.5.3.1 Phytoremediation

Phytoremediation involves growing plants in wastes or soil. Plants established in the impacted soil uptake COCs and incorporate the chemicals in their plant structures. Plants that have accumulated the COCs in their biomass are subsequently harvested for disposal at an off-site, permitted waste management facility. The most important limitation to phytoremediation is rooting depth, which can be 0.5, 1, or 3 feet bgs, depending on the plant and soil type. Therefore, one of the favorable site conditions for phytoremediation is that contamination be restricted to surface soil (U.S. EPA, 1997j).

Lead, which is present at low concentration is shallow soil at numerous RAP sites and RMP locations at the OARB, is difficult for plants to uptake (U.S. EPA, 1997j). In addition, the length of time to cleanup sites may be too long to be acceptable for most redevelopment objectives (U.S. EPA, 2001c). The natural growth rates of plants and the length of the growing season limits how quickly phytoremediation can uptake COCs.

Other suitable and more reliable processes exist for removing or treating COCs detected in soil at RAP sites and RMP locations at the OARB. Nevertheless, phytoremediation is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of this process option.

8.2.5.3.2 Bioremediation

Bioremediation involves stimulating indigenous microorganisms, such as bacteria and fungi, to transform hazardous chemicals to less toxic or non-toxic chemicals. Oxygen, water, and nutrients are supplied to wastes or soil to promote biological transformation of petroleum hydrocarbons or other organic chemicals under aerobic (i.e., presence of oxygen) conditions. Bioremediation of COCs, such as chlorinated organic solvents, may also occur under anaerobic (i.e., lack of oxygen) conditions. The applicability of bioremediation depends on the biodegradability of COCs at a site. Petroleum hydrocarbons, such as gasoline and diesel fuel, are known to be readily biodegradable. Other biodegradable COCs include alcohols, phenols, esters, and ketones. Chlorinated organic solvents become more difficult to biodegrade as the number of chlorine atoms increases (U.S. EPA, 1991c).

Although most chemical releases at RAP sites and RMP locations at the OARB involve petroleum hydrocarbons, the volume of impacted soil at each RAP site or RMP location is small and does not lend itself to economical in-situ bioremediation. In-situ bioremediation of soil may be accomplished as part of in-situ bioremediation of groundwater, but it is not relied upon as a stand-alone process option for impacted soil at RAP sites and RMP locations at the OARB. Although remedial alternatives in Section 9 do not incorporate in-situ bioremediation of soil, the process option is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of in-situ bioremediation of soil.

8.2.6 Soil Excavation

Excavation of soil with COCs is a general response action often implemented at sites where releases of hazardous substances have occurred. Excavation is typically accomplished with earth-moving equipment, such as backhoes, bulldozers, and front loaders. Excavating and removing waste materials, waste residues, and contaminated subsoil, also known as clean closure, will eliminate potential long-term risks to humans at RAP sites and RMP locations at the OARB. Although no volume limit has been established for determining the practicality of excavation, U.S. EPA (1996a, 1993c) states that landfills and sites with "a content of 100,000 cubic yards (approximately two

acres, 30 feet deep) would normally not be considered for excavation." Soil excavation is **retained** for further consideration.

8.2.7 Ex-situ Soil Treatment

Ex-situ soil treatment requires that soil with COCs be excavated before remedial technologies that destroy COCs, or reduce their toxicity or mobility are employed. Soil is treated aboveground. Ex-situ soil treatment consists of physical / chemical, thermal, and biological remedial technologies.

8.2.7.1 Ex-situ Soil Treatment Using Physical / Chemical Technology

Soil washing and immobilization are the process options considered in this RAP that use physical / chemical technology for ex-situ treatment of soil.

8.2.7.1.1 Soil Washing

Soil washing is sometimes referred to as hydrometallurgical separation. Soil washing is a presumptive remedy for soil with metals that pose a principal threat (U.S. EPA, 1999a). The process requires intimate contact of metal-containing soil with the extraction solution. The presence of large clumps or debris interferes with good contact, so pretreatment to exclude or crush oversize material normally is required. The extraction solution is routinely treated during soil washing to remove accumulated metals. Reuse of the solution is required because the leaching chemicals in the solution tend to be expensive and the disposal cost would be prohibitive if the volume of waste extraction solution was not reduced through recycling (Smith et al, 1995).

Extraction solutions used in soil washing are specific to a limited range of metal species. Thus, most extraction solutions are effective only for a narrow range of metal and soil type combinations (U.S. EPA, 1999a). The extraction solutions may also have toxic characteristics. In spite of these difficulties and the fact that, except for a few isolated samples, metals in soil at identified RAP sites and RMP locations have been detected at relatively low concentrations, soil washing is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of this process option.

8.2.7.1.2 Chemical Oxidation / Reduction

As described in Section 8.2.10.1.3, chemical oxidation or reduction processes are most commonly applied to transform COCs that are dissolved in groundwater as opposed to COCs sorbed to soil. U.S. EPA has recently studied the potential applicability of

chemical oxidation / reduction processes developed to destroy chemical weapons to the treatment of contaminated soil. The results of this study (U.S. EPA, 2000d) find that most chemical oxidation / reduction processes are not yet commercially available for the treatment of contaminated soil. According to U.S. EPA (2000d), the limited processes that do exist for full-scale applications appear to be permitted for treatment of PCBs only and require extensive preprocessing of soil before the PCBs can be transformed by chemical oxidation / reduction.

Chemical oxidation / reduction of COCs in soil is still in the development phase. Chemical oxidation / reduction is **not retained** for further consideration because other suitable and more reliable processes exist for removing or treating COCs detected in soil at identified RAP sites and RMP locations at the OARB.

8.2.7.1.3 Immobilization

Because vigorous mixing is needed to disperse solidification or stabilization chemical reagents with affected soil, immobilization is often performed aboveground. Immobilization, which is described in Section 8.2.5.1.2, refers to processes that change the toxicity, or physical or leaching characteristics of COCs in soil by mixing chemical reagents with impacted soil.

Pretreatment is generally performed to separate and crush oversize materials, such as rocks and debris, which can interfere with mixing of chemical reagents. Mixing can be accomplished by a variety of methods, including in-drum, in-plant, or area mixing. In-drum mixing is typically used for highly toxic or small volumes of wastes, and involves combining the reagents and wastes in a small (e.g., 55-gallon) drum. In-plant mixing may consist of either continuous or batch operations. Batch operations generally use a rotary drum mixer. A rotary drum mixer is a slightly inclined vessel, usually with internal baffles, that rotates to tumble and combine the contents. Continuous operations generally involve a pug mill. A pug mill has paddles attached to a horizontal rotating shaft to accomplish mixing. Area mixing entails placing layers of reagent and soil in a bermed location and combining the layers with a backhoe or other earth-moving equipment. Area mixing differs from in-situ immobilization using earth-moving equipment in that the affected soil is excavated and moved to a bermed location for treatment.

The effectiveness of immobilization to reduce the toxicity of metals is well demonstrated (U.S. EPA, 1999a, 1997j, 1993d). The former ORP / Building 1 area is the only identified RAP site or RMP location that contains high concentrations of metals for which ex-situ immobilization would be potentially applicable. The low pH and

heterogeneous nature of the tarry residue may make ex-situ immobilization of metals difficult. Treatability studies would need to be performed on the tarry residue to confirm the efficacy of this technology.

On-site disposal of stabilized tarry residue is anticipated to conflict with planned land uses (see Section 8.2.8.1). The greatest benefit of immobilizing tarry residue would result from disposing the stabilized material at an off-site permitted waste management facility in combination with a variance from land disposal restrictions ("LDR") treatment standards. Without a variance, underlying hazardous constituents, such as PAHs, PCDDs, and PCDFs, in the tarry residue may require that this material be incinerated to meet RCRA regulations. Incineration of the tarry residue is likely to be cost prohibitive and may necessitate that the untreated material be left in-place at the OARB, which would severely restrict redevelopment opportunities for the OARB. Ex-situ immobilization at the former ORP / Building 1 area is **retained** for further consideration.

8.2.7.2 Ex-situ Soil Treatment Using Thermal Technology

Thermal desorption, vitrification, and incineration are the process options considered in this RAP that use thermal technology for ex-situ treatment of soil.

8.2.7.2.1 Thermal Desorption

Thermal desorption is any of a number of processes that use either indirect or direct heat exchange to vaporize COCs from excavated soil. Air, combustion gas, or inert gas is used as the transfer medium for the volatilized COCs. Thermal desorption systems provide physical separation and are not designed to destroy COCs. Soil is typically heated to 200 to 1,000°F depending on the thermal desorption system selected. COCs in the off-gas may be incinerated in an afterburner, adsorbed onto vapor-phase GAC, or recovered in condensation equipment.

Thermal desorption has been proven effective in treating VOCs, petroleum hydrocarbons, and some SVOCs (U.S. EPA, 1991f). However, the process is energy intensive and requires that a large volume of soil be treated and reused on-site to justify the costs of the technology. It is not anticipated that soil volumes large enough to allow cost-effective treatment by thermal desorption would be generated at any one time. Most contaminated soil at the OARB will be addressed when it is encountered during infrastructure replacement that will be accomplished over a period of five years following base transfer. Although remedial alternatives in Section 9 do not incorporate thermal desorption, the process is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of thermal desorption.

8.2.7.2.2 Vitrification

Vitrification described in Section 8.2.5.2 can be performed ex-situ as well as in-situ. However, the availability of equipment limits implementability of vitrification (U.S. EPA, 1999a). The process is expensive to implement with costs highly dependent upon local energy rates, and the characteristics of deposited wastes and soils with COCs. For these reasons, vitrification is **not retained** for further consideration.

8.2.7.2.3 Incineration

Incineration involves burning wastes to destroy organic compounds. Incineration employs temperatures typically in the range of 1,500 to 3,000°F to convert organic compounds into water, carbon dioxide, and nitrogen oxides (Freeman, 1989). Depending upon the waste types to be destroyed, incinerators may consist of liquid-injection incinerators, rotary kilns, fluidized bed systems, hazardous waste boilers, or cement kilns. Metals are not destroyed by incineration. Metals either volatilize or remain in ash. Incineration is expensive because it is an energy-intensive process.

Unless a variance is obtained, incineration of tarry residue at the former ORP / Building 1 area may be necessary to comply with LDR treatment standards if this material is excavated for off-site disposal. Such treatment is likely to be cost-prohibitive if required. As a consequence, incineration is **not retained** for further consideration.

8.2.7.3 Ex-situ Soil Treatment Using Biological Technology

Phytoremediation and bioremediation are the process options considered in this RAP that use biological technology for in-situ treatment of soil.

8.2.7.3.1 Phytoremediation

Phytoremediation described in Section 8.2.5.3.1 can be performed on excavated soil that has been transferred to a bermed location to contain water used to irrigate the plants established in the affected soil. Phytoremediation is **not retained** because the length of time to remediate soil is likely to be too long to be compatible with redevelopment of the OARB. Other suitable and more reliable processes exist for removing or treating COCs detected in soil at identified RAP sites and RMP locations at the OARB.

8.2.7.3.2 Bioremediation

Bioremediation described in Section 8.2.5.3.2 can be performed ex-situ as well as in-situ. Ex-situ bioremediation is capable of readily degrading petroleum hydrocarbons and other fuel constituents found at identified RAP sites and RMP locations at the OARB. Unlike in-situ bioremediation, ex-situ bioremediation would allow impacted soil from various locations at the OARB to be aggregated at a location on the OARB for more cost-effective treatment. This process option is **retained** for further consideration.

8.2.8 Excavated Soil Management

Soil that has been excavated and soil that has been excavated and treated must eventually be disposed either on-site or off-site.

8.2.8.1 Disposal of Soil On-site

Except for the former ORP / Building 1 area, soil with COCs most likely can be treated to concentrations less than applicable remediation goals that would allow disposal or reuse at the OARB. Treatment and on-site disposal of tarry residue from the former ORP / Building 1 area is problematic because available data suggest that some portion of the tarry residue may be classified as a RCRA hazardous waste due to corrosivity or toxicity. Unless this material is incinerated, it is likely to contain PAHs, PCDDs, and PCDFs at concentrations greater than site-specific remediation goals and possibly greater than LDR treatment standards for RCRA hazardous waste. Excavated contaminated soil from the former ORP / Building 1 area that does not meet LDR treatment standards may have to be placed in a corrective action management unit ("CAMU") pursuant to 22 CCR §66264.552 if the soil is to remain on-site. Creation of a CAMU, which is functionally a RCRA landfill, on the OARB is incompatible with planned redevelopment. As a consequence, on-site disposal is **retained** for further consideration for excavated soil that has been appropriately treated.

8.2.8.2 Disposal of Soil Off-site

Off-site disposal of soil entails directly transporting excavated material to a permitted waste management facility. Excavated soil and waste must be characterized to determine the type of waste management unit or facility that is permitted to accept the material for disposal. The State of California regulates three specific types of waste management units. These waste management units consist of Class I units that receive hazardous wastes, Class II units that receive designated wastes, and Class III units that receive non-hazardous solid wastes.

Disposal of hazardous wastes is regulated under Title 22 of the CCR. Hazardous wastes are those wastes that are listed to be hazardous or exhibit hazardous characteristics as defined by DTSC or U.S. EPA under RCRA. Disposal of designated and non-hazardous solid wastes is regulated under Title 27 of the CCR. Designated wastes are non-hazardous wastes that contain soluble pollutants in concentrations that exceed applicable water quality objectives or could degrade waters of the state. As discussed in Section 6, non-hazardous solid wastes are defined under 27 CCR §20220 as the following:

> Nonhazardous solid waste means all putrescible and nonputrescible solid, semi-solid, and liquid wastes, including garbage, trash, refuse, paper, rubbish, ashes, industrial wastes, demolition and construction wastes, abandoned vehicles and parts thereof, discarded home and industrial appliances, manure, vegetable or animal solid and semi-solid wastes and other discarded waste (whether of solid or semi-solid consistency); provided that such wastes do not contain wastes which must be managed as hazardous wastes, or wastes which contain soluble pollutants in concentrations which exceed applicable water quality objectives, or could cause degradation of waters of the state (i.e., designated waste).

Investigations performed at RAP sites and RMP locations at the OARB suggest that most soil with COCs meets the definition of non-hazardous solid waste and is so mildly contaminated that it can be possibly used as daily cover over a waste management unit at an off-site, permitted facility.

Daily cover is defined in 27 CCR §20164 as cover material placed on the surface of the active face of a waste management unit at the end of each operating day to control disease vectors, fire, odors, blowing litter, and scavenging. By using mildly contaminated soil instead of clean soil for daily cover, a waste management facility can receive tax benefits because the contaminated soil is considered recycled material. Available tax benefits to a facility can translate into acceptance of mildly contaminated soil at a reduced rate. For example, disposing of soil as a Class II waste may incur a disposal cost on the order of $60/ton. In comparison, disposing of soil as cover material can cost approximately $30/ton.

Any off-site disposal of RCRA hazardous waste, such as tarry residue at the former ORP / Building 1 area, must comply with LDRs (U.S. EPA, 2001b). Treatment to meet LDRs prior to land disposal could include incineration, stabilization, or other technologies. As the required treatment would be conducted at the off-site, permitted disposal facility, any

technology required to comply with LDRs is included as off-site disposal. Off-site disposal is **retained** for further consideration.

8.2.9 Groundwater Diversion

Relatively few RAP sites or RMP locations at the OARB involve impacted groundwater. Low concentrations of VOCs, BTEX, MTBE, and petroleum hydrocarbons are found in groundwater at these RAP sites and RMP locations. Impacts are limited and COCs do not appear to be migrating in groundwater at any of the sites affected. Regardless of these facts, groundwater collection/diversion technologies have been screened to assess their implementability at identified RAP sites and RMP locations at the OARB.

8.2.9.1 Subsurface Barriers

Subsurface barriers, such as a slurry wall or sheet piling, are vertical structures installed into the subsurface to contain or redirect groundwater flow. Subsurface barriers are often used in conjunction with groundwater extraction to maintain hydraulic control. To be effective, a subsurface barrier must be completed or "keyed" into a continuous layer of clay deposits or competent bedrock. This layer must have sufficiently low permeability to prevent leakage underneath the barrier, it must have adequate thickness for an appropriate key (e.g., 2 to 3 feet), and it must be of moderate depth (50 to 70 feet bgs) or installation of the subsurface barrier may not be feasible (U.S. EPA, 1991c).

8.2.9.1.1 Slurry Wall

A slurry wall is constructed by excavating a narrow trench, typically 2 to 4 feet wide, and backfilling it with low-permeability material. As excavation proceeds, a bentonite-water mixture is temporarily placed in the trench to stabilize the trench walls, thereby preventing collapse. The bentonite-water mixture also permeates into the soil and creates a filter cake on the walls that seals the soil to prevent loss of the low-permeability slurry that will be used to permanently fill the trench.

Slurry walls are differentiated by the materials used to permanently fill the trench. If slurry of soil, bentonite, and water is employed, then the wall is known as a soil-bentonite slurry wall. In some cases, slurry of portland cement, bentonite, and water is employed. This type of wall is referred to as a cement-bentonite slurry wall. Cement-bentonite slurry walls are used at sites where there is inadequate space to place and mix soil with bentonite and water, or where increased wall strength may be necessary. Cement-bentonite slurry walls may also be used where the site topography makes it impractical to install a soil-bentonite slurry wall. Soil-bentonite slurry will flow if the

trench is not within a few degrees of level. Cement-bentonite walls that harden quicker are better suited to irregular topography.

Creation of grout curtains is another process by which low-permeability materials are introduced into the subsurface. The grout is pressure injected into soil or rock. Grout types are divided into particulate grout, and chemical grout. Particulate grouts are fluids that consist of a suspension of cement, clay, bentonite, or a combination of these materials in water. Chemical grouts rely on polymerization reactions to form hardened gels. Chemical grouts include portland cement, cement-bentonite, silicate, and organic polymer mixtures.

Both slurry walls and grout curtains are feasible to implement because these subsurface barriers can be keyed into the low permeability Young Bay Mud that underlies the shallow water-bearing zone at the OARB. However, grout curtains are seldom used for diverting groundwater flow. Slurry walls are less costly and have lower permeability than grout curtains. Grouting is best suited for sealing voids or fractures in bedrock (U.S. EPA, 1991c).

Groundwater diversion may be required if tarry residue is excavated at the former ORP / Building 1 area since some of this material may be present below the groundwater surface in the shallow water-bearing zone. Regarding the removal of tarry residue, IT (2001i) has stated:

> It is, however, probable that a portion of the excavation would need to be conducted below the water table. Experience at OARB indicates that dewatering is difficult, particularly if it involves the highly permeable sand layer underlying the gravelly fill layer. Practice for tank removal at OARB under this situation has been to conduct limited wet excavation in the water table.

In the event that groundwater infiltration is so high that it prevents dewatering of the excavation, subsurface barriers may have to be temporarily installed to divert groundwater from flowing into the excavation. Although remedial alternatives in Section 9 do not incorporate use of a slurry wall, the process is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of a slurry wall.

8.2.9.1.2 Sheet Piling

Sheet piling can consist of interlocking steel, precast concrete, or wood sections. In most applications to divert groundwater flow, steel is employed because concrete is used only in a situation where great lateral resistance is required and wood is a poor barrier against groundwater flow. Steel sheet piling is installed by driving individual sections into the ground with single, double-action impact or vibratory pile drivers. One of the biggest drawbacks of sheet piling is that it is difficult to install in rocky soil. Damage to or deflection of the steel sections is likely to render sheet piling ineffective as a groundwater barrier. Further, it is difficult to use sheet piling for deep groundwater situations because of limitations in the depth that piling can be driven. The maximum depth to which sheet piling can be driven without damage to the interlocks between individual sections is approximately 40 feet bgs (U.S. EPA, 1991c).

Despite these drawbacks, sheet piling can often be installed quicker and at less expense than slurry walls. As discussed in Section 8.2.9.1.1, sheet piling may be effective in reducing the inflow of groundwater while excavating contaminated soil. The temporary use of sheet piling under such circumstances is considered ancillary to the application of the technology to contain or divert contaminated groundwater. Use of sheet piling is **not retained** for further consideration.

8.2.10 In-situ Groundwater Treatment

In-situ groundwater treatment consists of remedial technologies that destroy COCs or reduce their toxicity or mobility without having to extract groundwater.

8.2.10.1 <u>In-situ Groundwater Treatment Using Physical / Chemical Technology</u>

Air sparging, reactive walls, and oxidation / reduction are the process options considered in this RAP that use physical / chemical technology for in-situ treatment of groundwater.

8.2.10.1.1 Air Sparging

Air sparging, recirculating wells, and other similar processes cause VOCs and other volatile compounds to partition from groundwater into an air stream. The air stream containing VOCs is collected through an SVE system for subsequent treatment in most applications. Air sparging is potentially capable of remediating impacted groundwater at the OARB. This technology is **retained** for further consideration.

8.2.10.1.2 Permeable Reactive Walls

Permeable reactive walls consist of a permeable and reactive medium installed in a trench constructed across the groundwater flow path. A permeable reactive wall allows passage of groundwater while transforming COCs to harmless byproducts. The Ground-Water Remediation Technologies Analysis Center ("GWRTAC")[22] indicates in its technology evaluation report, entitled *Treatment Walls,* dated October 1996, that zero-valent iron is the most common reactive medium used in permeable reactive walls.

A primary design concern of a permeable reactive wall is ensuring that COC-containing groundwater passes through the structure (U.S. EPA, 1998a). The medium in the permeable reactive wall should be at least as permeable as the soil in the saturated zone. In some cases, a subsurface barrier (e.g., interlocking sheet piling) is installed along the edges of the area containing groundwater with dissolved COCs. The barrier is installed in a configuration similar to a funnel, directing groundwater to flow through the permeable reactive wall, or "gate," at the down gradient end of the "funnel." This arrangement is called a "funnel and gate" design, and can be used to improve confidence in the capture of impacted groundwater.

A primary operational concern with permeable reactive walls is the longevity of the system (U.S. EPA, 1998a). Plugging or coating of the reactive medium can occur if minerals precipitate in or on the medium (e.g., calcium carbonate scale). The reductive dehalogenation process of chlorinated organic solvents tends to increase the pH of the groundwater, enhancing the tendency for scale formation. To mitigate this concern, designs have been developed that allow for periodic replacement or cleaning of the reactive medium.

Use of permeable reactive walls is an emerging physical / chemical process. Application of the process is limited. As of 1998, only thirteen full-scale permeable reactive walls had been installed throughout the United States. These walls were treating either chlorinated organic solvents or hexavalent chromium in groundwater using zero-valent iron as the reactive medium (GWRTAC, 1999; U.S. EPA, 1998a, 1997g, 1995c). BTEX, MTBE, and petroleum hydrocarbons, which are found in groundwater at certain identified RAP sites and RMP locations at the OARB, are not amenable to treatment by

[22] GWRTAC is operated by Concurrent Technologies Corporation ("CTC"), in association with the University of Pittsburgh, through a cooperative agreement with U.S. EPA Technology Innovation office. According to CTC, GWRTAC reports are developed to provide a state-of-the-art review of a selected groundwater remediation technology or groundwater topic. GWRTAC reports contain information from peer-reviewed papers and publications, and in some instances, from personal communication with involved parties. GWRTAC reports are peer-reviewed before being released.

this technology. Implementation of permeable reactive walls is **retained** for possible future use in the event site conditions at the OARB are found to warrant application of this process option.

8.2.10.1.3 Chemical Oxidation / Reduction

In-situ chemical oxidation or reduction processes involve injecting a chemical oxidant or reductant directly into saturated soil. Common oxidants include hydrogen peroxide and potassium permanganate. Reductants include sodium dithionite and hydrogen sulfide (GWRTAC, 1999; U.S. EPA, 1998b). The desired result of oxidation / reduction treatment is the complete transformation of COCs in groundwater to less toxic or non-toxic organic species, or water, carbon dioxide, and chloride ions.

The stratigraphy and geochemistry at a given site control the ability, amounts, and types of oxidants or reductants that must be delivered to the saturated zone. For example, if hydrogen peroxide is used to oxidize COCs in groundwater, the pH of saturated soil may have to be temporarily lowered and ferrous iron or other catalyst may have to be injected to facilitate the oxidation reaction.

In-situ chemical oxidation / reduction may be appropriate for RAP sites and RMP locations at the OARB with impacted groundwater. The low groundwater velocity observed at the OARB suggests that groundwater extraction may not be necessary to control undesired migration of oxidants and reductants introduced into the subsurface. In-situ chemical oxidation / reduction is an emerging physical / chemical process. Treatability studies will likely be required to evaluate the efficacy of the process at the OARB. In-situ oxidation / reduction is **retained** for further consideration.

8.2.10.2 <u>In-situ Groundwater Treatment Using Biological Technology</u>

Bioremediation is the only process considered in this RAP that uses biological technology for in-situ treatment of groundwater. Bioremediation described in Section 8.2.5.3.2 can be performed by introducing oxygen and/or nutrients to groundwater. Bioremediation has been demonstrated for residual concentrations of VOCs and petroleum hydrocarbons similar to those found in groundwater at identified RAP sites and RMP locations at the OARB. One simple approach for accomplishing in-situ aerobic bioremediation is to inject Oxygen Release Compound™ ("ORC") or similar products into the subsurface with direct push technology ("DPT"). Vinyl chloride, cis-1,2-DCE, trans-1,2-DCE, and MTBE are amenable to aerobic bioremediation. Regarding vinyl chloride, which is a primary COC in shallow groundwater at Building 807, Buildings 808 and 823, and Building 99, U.S. EPA (2000f)

states that vinyl chloride is "more commonly remediated using aerobic mechanisms than anaerobic mechanisms." Alternatively, anaerobic bioremediation of more chlorinated VOCs, such as TCE or tetrachloroethene ("PCE") can be accomplished by injecting molasses or commercially available mixtures, such as Hydrogen Release Compound™ ("HRC"), into the subsurface with DPT. In-situ bioremediation is **retained** for further consideration.

8.2.11 Groundwater Extraction

Extraction provides hydraulic containment of chemical-containing groundwater by altering the direction of groundwater flow through creation of a depression in the piezometric surface. Extracted groundwater containing COCs must be treated or otherwise managed. Possible ex-situ treatment and management approaches are described in Sections 8.2.12.1 and 8.2.13, respectively.

Although extraction and ex-situ treatment is a presumptive remedy for sites with contaminated groundwater, restoration of chemical-containing groundwater generally will not be possible unless the source of COCs has been addressed. U.S. EPA (1996b) states that "source control is a critical component for active restoration remedies (e.g., extraction and treatment and in-situ methods) as well as for natural attenuation."

The characteristics of the chemicals released and the hydrogeologic properties of the site govern the potential for restoring groundwater to cleanup levels defined by ARARs or risk-based levels (U.S. EPA, 1996b). Relevant chemical characteristics include its volatility, how strongly it sorbs to soil, its potential for natural attenuation, quantities in which it was released, and whether it has formed NAPL. Relevant hydrogeologic properties include the stratigraphy (e.g., degree of interbedded and discontinuous soil layers), types (e.g., sand or clay) and heterogeneity of soil present, saturated soil hydraulic conductivity, extent of vertical groundwater flow, and temporal variation in the rate of groundwater movement.

8.2.11.1 Wells

Although horizontal wells can be constructed for extraction of groundwater, vertical wells are almost exclusively used because of the relative ease and lower cost of construction. Vertical wells can be completed to essentially any depth and at any location that allows access for the drilling equipment. Vertical wells are strategically placed to contain and collect the groundwater with COCs. Wells are **retained** for further consideration.

8.2.11.2 Trenches

Trenches or drains may be used to collect groundwater. Drains are typically installed perpendicular to the direction of groundwater flow. Drains are constructed by excavating a trench and installing perforated pipe on aggregate base laid at the bottom of the trench.

The portion of the trench in saturated soil is then backfilled with aggregate or other envelope material. The remainder of the trench is backfilled with soil. A geotextile may also be installed in the trench to prevent fine soil particulates from clogging the drain. If the saturated soil has a moderate or high hydraulic conductivity, then a low-permeability geomembrane may be placed on the down gradient side of the trench to prevent groundwater from passing through the drain. Gravity drains could discharge to a sanitary sewer manhole, storm drain manhole or catch basin, or directly to a free-flowing stream or creek, if there is enough slope to the terrain. If the drain terminates below the entry point to the sewer, storm drain, or water body, a pump would be necessary to lift the water to the discharge point.

Trench excavation is also complicated by underground utilities, or in areas where buildings and roads exist. Despite these limitations, drains may be more cost effective in certain circumstances. Drains may be particularly well suited to sites with relatively low hydraulic conductivities, where the costs to install wells may be high because of the need to locate wells close together. Use of trenches or drains is **retained** for further consideration.

8.2.12 Ex-situ Groundwater Treatment

Ex-situ groundwater treatment is necessary only if extraction is performed. Ex-situ groundwater treatment consists of physical / chemical and biological remedial technologies.

8.2.12.1 Ex-situ Groundwater Treatment Using Physical / Chemical Technology

Air stripping, adsorption, membrane separation, precipitation/coagulation, ion exchange, and advanced oxidation are the process options considered in this RAP that use physical / chemical technology for ex-situ treatment of groundwater.

8.2.12.1.1 Air Stripping

Air stripping is a physical process that transfers VOCs from water to air. VOC-containing groundwater is pumped to the top of a tower and distributed across trays

or random packing. The water flows downward as a thin film across these surfaces. Air is blown into the base of the tower and travels upward. The trays or packing in the tower provide a large surface area and the flow of air creates a high level of turbulence. These two factors enhance mass transfer to the air. Subsequent treatment is often performed to recover or destroy VOCs in the air stream leaving the top of the tower.

Air stripping is a presumptive remedy for treatment of VOCs in groundwater (U.S. EPA, 1996b). Air stripping may have to be used in combination with adsorption to remove less volatile compounds such as petroleum hydrocarbons if present in extracted groundwater. Air stripping alone or in combination with adsorption is considered a contingent process option for treating groundwater at RAP sites at the OARB. Air stripping is **retained** for further consideration.

8.2.12.1.2 Adsorption

Adsorption of COCs onto GAC, activated alumina, or other media is commonly used for treatment of chemical-containing groundwater. The media is placed as columns or beds in cylindrical vessels. GAC adsorption is a presumptive remedy for treatment of organic compounds in groundwater (U.S. EPA, 1996b). Physical adsorption of COCs onto GAC results from the action of van der Waals forces, which are relatively weak interactions produced by the motion of electrons in their orbitals. Adsorption is **retained** for further consideration.

8.2.12.1.3 Membrane Separation

Membrane separation includes reverse osmosis, ultrafiltration, and electrodialysis. These processes involve forcing chemical-containing groundwater through a semi-permeable membrane to separate the COCs in a concentrate stream and clean water in a permeate stream. Reverse osmosis is a presumptive remedy for treatment of metals in groundwater (U.S. EPA, 1996b). U.S. EPA also designated reverse osmosis as BAT in its establishment of the lead and copper rule for drinking water (40 CFR §141). Reverse osmosis was found to remove lead to concentrations of 5 µg/L (53 FR 31516-31578). Extraction to remove metals in groundwater is not anticipated because metal concentrations detected in the shallow water-bearing zone do not now, and will not in the future, pose potential risks to human health and the environment. Membrane separation is **not retained** for further consideration.

8.2.12.1.4 Precipitation/Coagulation

Precipitation involves mixing chemical reagents in water to convert soluble COCs to insoluble forms. Coagulation involves mixing chemical reagents in water to cause soluble COCs to aggregate into flocs. Precipitates and flocs are subsequently removed from water by settling and/or filtration. Precipitation/coagulation is a presumptive remedy for treatment of metals in groundwater (U.S. EPA, 1996b) and is BAT for treatment of lead and copper in drinking water (40 CFR §141). Although precipitation/coagulation can reduce lead concentrations to approximately 5 µg/L, it is unlikely that extraction will be conducted for the purpose of removing metals from the shallow water-bearing zone at the OARB. This process option is **not retained** for further consideration.

8.2.12.1.5 Ion Exchange

Ion exchange captures ionic COCs in groundwater on a resin. The resin is placed as columns or beds in cylindrical vessels. According to Freeman (1989), ion exchange resins can be described "simply as solid, insoluble acids or bases that are capable of entering into chemical reactions in the same way as their mineral or organic acid analogs."

Ion exchange is a presumptive remedy for treatment of metals in groundwater (U.S. EPA, 1996b) and is BAT for treatment of lead and copper in drinking water (40 CFR §141). Although ion exchange can reduce lead concentrations to approximately 5 µg/L, it is unlikely that extraction will be conducted for the purpose of removing metals from the shallow water-bearing zone at the OARB. This process option is **not retained** for further consideration.

8.2.12.1.6 Advanced Oxidation

Advanced oxidation entails using strong oxidants to destroy COCs in groundwater. Common oxidants include hydrogen peroxide, ozone, and ultraviolet light. These oxidants can be used alone or in combination to destroy COCs. Advanced oxidation is a presumptive remedy for treatment of organic compounds in groundwater (U.S. EPA, 1996b). Advanced oxidation is **retained** for further consideration.

8.2.12.2 Ex-situ Groundwater Treatment Using Biological Technology

Bioremediation described in Section 8.2.5.3.2 can be performed ex-situ as well as in-situ. Bioremediation is **not retained** for further consideration because COCs are present at

low concentrations in groundwater that make it difficult to maintain the performance of ex-situ biological treatment systems. Other suitable and more reliable processes exist for treating groundwater in the event extraction must be conducted at identified RAP sites at the OARB.

8.2.13 Extracted Groundwater Management

In the event that groundwater and surface water is extracted or collected from RAP sites at the OARB, the resulting water produced must be managed. Potential means of management evaluated in this RAP consist of reclamation, discharge to the sanitary sewer, and discharge to the storm drain.

8.2.13.1 Groundwater Reclamation

No opportunities for reclamation of treated groundwater have been identified at the OARB. The areas with impacted groundwater are limited in size and the VOC or fuel constituent concentrations in groundwater at these areas are relatively low. These conditions suggest that extraction would have to be performed for only a short duration (i.e., on the order of five years) to remediate groundwater at the affected RAP sites. If groundwater extraction were to be implemented as a remedial action, it would most probably be conducted at RAP sites within the first five years after transfer of the OARB. Redevelopment activities occurring during this time frame are anticipated to consist primarily of infrastructure replacement. No irrigation systems, ponds, or water features that may be part of redevelopment of the OARB and could potentially accept treated water will be designed or constructed within the period that groundwater extraction would most likely be accomplished at the OARB. Reclamation is **not retained** for further consideration.

8.2.13.2 Groundwater Discharge to Sanitary Sewer

EBMUD operates the POTW that treats the sanitary sewer effluent from the OARB. Although COCs in groundwater at certain RAP sites are greater than site-specific remediation goals, concentrations of these chemicals are generally less than the numerical limitations on wastewater discharge to the sanitary sewer established by EBMUD (Table 6-3). These circumstances would suggest that extracted groundwater could be disposed to the sanitary sewer without having to be treated, but this is generally not the case. Section 5 of Title I of EBMUD Ordinance 311 prohibits the discharge of storm, drainage, and groundwater to the POTW. However, the ordinance allows EBMUD to enter into an agreement under "unusual conditions" that compels special terms and fees for POTW treatment of groundwater. As a means of discouraging discharge of

groundwater to the sanitary sewer, EBMUD typically levies higher fees for POTW treatment and imposes much stricter numerical limitations than those established for wastewater discharge. In some instances, the limitations are so low that available treatment technology is incapable of consistently removing COCs to meet the discharge limitations. For these reasons, discharge of treated groundwater to the sanitary sewer is **not retained** for further consideration.

8.2.13.3 Groundwater Discharge to Storm Drain

Discharge of treated groundwater to the storm drain may require a NPDES permit depending upon whether the discharge to the receiving water is determined to occur on-site or off-site. RWQCB (2001c) has adopted NPDES General Permit No. CAG912002 for discharge of groundwater that has been treated for impacts by petroleum fuel releases. NPDES General Permit No. CAG912003 has been adopted for discharge of groundwater that has been treated for impacts by VOC releases (RWQCB, 1999a). Treated groundwater conveyed to storm drains at the OARB may need coverage under these general permits or a site-specific permit may have to be obtained from RWQCB.

Before authorization is granted to discharge treated groundwater to surface water under General Permits Nos. CAG912002 and CAG912003, a demonstration must be made to the RWQCB that it is technically or economically infeasible to reclaim the water or discharge it to a POTW. As discussed in Sections 8.2.13.1 and 8.2.13.2, neither reclamation nor discharge to the sanitary sewer at the OARB is judged to be technically feasible. Discharge to the storm drain is **retained** for further consideration.

8.3 SUMMARY OF TECHNOLOGIES RETAINED FOR FURTHER CONSIDERATION

Based upon the results of screening performed in Section 8.2, the general response actions, remedial technologies, and process options retained for further consideration at this time, organized by medium, are as follows:

SOIL AND GROUNDWATER:

- No Action
- Institutional Controls
- Monitored Natural Attenuation

SOIL:

- Permeable Cover Systems
- Low-Permeability Cover Systems for Use as Vapor Barriers
- Sub-slab Depressurization or SSD
- Soil Excavation
- Ex-situ Immobilization
- Ex-situ Bioremediation
- Disposal of Soil On-site that has been Appropriately Treated
- Disposal of Soil Off-site

GROUNDWATER:

- Air Sparging
- In-situ Chemical Oxidation / Reduction
- In-situ Bioremediation
- Groundwater Extraction Using Wells or Trenches
- Ex-situ Groundwater Treatment Using Air Stripping, Adsorption, or Advanced Oxidation
- Groundwater Discharge to Storm Drain

Section 9 summarizes the development and screening of remedial alternatives using the technologies retained from this section. Section 10 presents the detailed analysis of alternatives.

9. DEVELOPMENT AND SCREENING OF ALTERNATIVES

General response actions, remedial technologies, and process options passing the screening performed in Section 8 have been developed into remedial alternatives for identified RAP sites and RMP locations at the OARB.

9.1 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Following the methodology in U.S. EPA (1988a) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, general response actions, remedial technologies, and process options for soil and groundwater have been combined to create potential alternatives that address COCs at identified RAP sites and RMP locations as a whole. A range of options has been developed that include the no action alternative; a limited action alternative consisting of groundwater monitoring only; groundwater response actions; and soil removal or soil removal and treatment response actions. Potential remedial alternatives for identified RAP sites and RMP locations at the OARB consist of the following:

- No action for soil and groundwater.
- Institutional controls.
- Monitored natural attenuation.
- Perform chemical oxidation / reduction in shallow water-bearing zone and monitor groundwater.
- Perform in-situ bioremediation in shallow water-bearing zone and monitor groundwater.
- Extract, perform ex-situ treatment, and discharge groundwater to the storm drain, and monitor groundwater.
- Perform air sparging in shallow water-bearing zone and monitor groundwater.
- Install vapor barrier beneath new building and monitor groundwater.
- Install vapor barrier with sub-slab depressurization system beneath new building and monitor groundwater.

- Excavate, conduct ex-situ bioremediation, and dispose of soil on-site, and monitor groundwater.
- Excavate and dispose of soil off-site, and monitor groundwater as needed.
- Excavate and dispose of soil off-site and perform in-situ treatment of shallow water-bearing zone and monitor groundwater.
- Excavate, conduct ex-situ immobilization, and dispose of soil off-site, and monitor groundwater.

Given the varied environmental conditions at identified RAP sites and RMP locations at the OARB, not all potential remedial alternatives will pertain to each site or location. For example, review of available analytical results indicates that a significant chemical source does not remain in soil where VOCs are present in shallow groundwater at the eastern end of Building 807. Therefore, remedial alternatives that involve soil excavation or soil excavation and treatment need not be considered for this RAP site.

9.2 SCREENING OF REMEDIAL ALTERNATIVES

To potentially reduce the remedial alternatives that must undergo detailed analysis, the NCP at 40 CFR §300.430(e)(7) provides the opportunity to screen alternatives against the short- and long-term aspects of the following three criteria:

- **Effectiveness:** Alternatives are judged on the degree to which an alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risks and affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection. Alternatives providing significantly less effectiveness than other, more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration.
- **Implementability:** This criterion focuses on the technical feasibility and availability of the technologies each alternative would employ and the administrative feasibility of implementing the alternative. Alternatives that are technically or administratively infeasible, or require equipment, specialists, or facilities that are not available within a reasonable period of time may be eliminated from further consideration.

- **Cost:** Costs of construction and any long-term costs to operate and maintain the alternatives shall be considered. Costs that are grossly excessive compared to the overall effectiveness of alternatives may be used as a factor to exclude alternatives from further consideration. Alternatives providing effectiveness and implementability comparable to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may also be eliminated.

Table 9-1 summarizes the screening of remedial alternatives against these three criteria. Screening of alternatives was conducted to eliminate from this current evaluation those remedial alternatives that can be eliminated based upon the criteria of effectiveness, implementability, and cost. However, in the event that additional future RAP sites or RMP locations are identified that may be amenable to remediation from a additional remedial alternatives, all remedial alternatives are retained for either current or potential future use. The nature and extent of COCs at RAP sites and RMP locations is described in Section 4.4 are used to determine which of the retained alternatives apply to individual sites and undergo detailed analysis in Section 10.

9.3 RESULTS OF REMEDIAL ALTERNATIVE SCREENING

Results of remedial alternative screening are discussed in Sections 9.3.1 through 9.3.13 and summarized in Table 9-2.

9.3.1 No Action for Soil and Groundwater

The no action alternative for soil and water will not achieve RAOs at identified RAP sites and RMP locations at OARB with COCs in soil or groundwater greater than screening levels for unrestricted use because this alternative does not include institutional controls to limit land and groundwater use. This alternative can be easily implemented and costs are negligible because no further activities need to be performed. The NCP at 40 CFR §300.430(e)(6) requires that the no action alternative be evaluated as a baseline for comparison of other alternatives developed. This alternative is **retained** for detailed analysis.

9.3.2 Institutional Controls

Institutional controls will be implemented at the entire OARB. Institutional controls are inherent components of all remedial alternatives evaluated in this RAP, with the exception of the no action alternative described in Section 9.3.1. Institutional controls

will restrict the OARB to commercial and industrial uses, prevent the use of groundwater, and obligate owners and tenants of the OARB to implement the procedures specified in the RMP and to update information in the RMP as appropriate. The institutional controls also include the maintenance of existing cover or construction of new cover at the RAP site or RMP location. This alternative is **retained** for detailed analysis.

9.3.3 Monitored Natural Attenuation

This alternative will be implemented at RAP sites or RMP locations found to have residual COCs in groundwater and no significant chemical source in soil. Examples where this alternative applies include the seven former petroleum tank locations where natural attenuation of petroleum hydrocarbons in shallow groundwater is being monitoring under supervision of RWQCB.

MNA is effective in mitigating the concentration trends of COCs in the shallow water-bearing zone over time and can be easily implemented. Implementation of the MNA alternative is expected to have low capital cost, and low to moderate annual cost. This alternative is **retained** for detailed analysis.

9.3.4 Perform Chemical Oxidation / Reduction in Shallow Water-Bearing Zone and Monitor Groundwater

In-situ chemical oxidation / reduction would involve using DPT to inject oxidants or reductants into the shallow water-bearing zone. This alternative is applicable to RAP sites that have chlorinated VOCs in groundwater. Potassium permanganate or hydrogen peroxide are two common chemical oxidants that could potentially be used to convert chlorinated VOCs to non-toxic compounds. The ability to implement this alternative is contingent upon the ease in which COCs present in groundwater can be chemically oxidized or reduced and the demand for oxidants or reductants exerted by saturated zone soil. Naturally occurring minerals in some soils can consume a large percentage of the oxidant or reductant introduced into the subsurface thereby rendering the alternative cost prohibitive when compared with other remedial actions. Treatability studies are required to confirm the efficacy of the process at the OARB.

Implementation of the alternative is expected to have low to moderate capital cost, and low to moderate annual cost. In-situ chemical oxidation / reduction is **retained** for detailed analysis.

9.3.5 Perform In-situ Bioremediation in Shallow Water-Bearing Zone and Monitor Groundwater

In-situ bioremediation would entail using DPT to inject ORC or a similar product into the shallow water-bearing zone. ORC is a proprietary formulation of magnesium peroxide. Upon contacting water, magnesium peroxide in ORC is converted to magnesium hydroxide and oxygen is liberated in the process, which is used by microorganisms to degrade COCs. The mass of ORC that must be injected into the shallow water-bearing zone depends upon the quantities of COCs and naturally occurring organic matter in the subsurface. If COCs and naturally occurring organic matter consume significant amounts of oxygen, the injection of ORC may have to be repeated more than once.

It is expected that this alternative can be readily implemented. Vinyl chloride and cis-1,2-DCE are the primary VOCs in groundwater near Buildings 808 and 823 and near Building 99. U.S. EPA (2000f) notes that vinyl chloride and cis-1,2-DCE can be aerobically degraded, and magnesium peroxide (e.g., ORC) is commonly added to the subsurface to facilitate in-situ bioremediation of these compounds. Although ORC has been demonstrated to assist with the degradation of vinyl chloride, cis-1,2-DCE and most petroleum constituents detected in the shallow water-bearing zone at the OARB, certain chlorinated VOCs, such as TCE, are resistant to aerobic biodegradation. In-situ biodegradation with HRC or in-situ chemical oxidation / reduction might be used at locations where TCE or other chlorinated VOCs with a greater number of chlorine atoms are found in shallow groundwater (e.g., at the eastern end of Building 807). It is also possible that after compounds that are readily degraded under aerobic conditions have been removed, it may be necessary to allow the system to revert to an anaerobic environment to facilitate the degradation of residual VOCs that may be resistant to aerobic degradation (e.g., PCE, TCE).

Implementation of in-situ bioremediation is expected to have low to moderate capital cost, and low to moderate annual cost. This alternative is **retained** for detailed analysis.

9.3.6 Extract, Perform Ex-situ Treatment, and Discharge Groundwater to the Storm Drain, and Monitor Groundwater

Extraction would be essential if hydraulic containment of impacted groundwater had to be achieved. However, review of available data does not suggest that this is case at the OARB. COCs do not appear to be migrating in groundwater at the OARB. Given that the areas impacted with COCs in groundwater are stable, the use of extraction to accomplish chemical removal is costly and may not be as effective as in-situ chemical oxidation / reduction or in-situ bioremediation.

Implementation of groundwater is expected to have moderate to high capital cost, and moderate to high annual cost. This alternative is **not retained** for detailed analysis. However, the alternative would be considered for detailed analysis in the future if site conditions warrant evaluation of this alternative.

9.3.7 Perform Air Sparging in Shallow Water-Bearing Zone and Monitor Groundwater

Air sparging could be performed at RAP sites with VOCs or fuel constituents in groundwater. Implementation of this alternative at the OARB is complicated compared with in-situ chemical oxidation / reduction or in-situ bioremediation. Air sparging requires the installation of wells, air compressors, vacuum pumps, SVE collection piping, and possible off-gas treatment systems that must operate and be maintained throughout the period that groundwater is being remediated. In-situ chemical oxidation / reduction or in-situ bioremediation involve the injection of chemical solutions into the subsurface that ideally is performed only once. The presence of air sparging equipment may be intrusive and hinder redevelopment activities.

Implementation of air sparging is expected to have moderate to high capital cost, and moderate to high annual cost. This alternative is **not retained** for detailed analysis because other suitable alternatives exist for removing or treating COCs detected in groundwater. However, the alternative would be considered for detailed analysis in the future if site conditions warrant evaluation of this alternative.

9.3.8 Install Vapor Barrier Beneath New Building and Monitor Groundwater

Incorporating the installation of a vapor barrier beneath new buildings would limit vapor intrusion of COCs into buildings. This alternative can be easily implemented during building construction. Implementation of the alternative is expected to have moderate capital cost, and low to moderate annual cost due to required groundwater monitoring. Installation of a vapor barrier beneath new buildings is **retained** for detailed analysis.

9.3.9 Install Vapor Barrier with Sub-slab Depressurization System Beneath New Building and Monitor Groundwater

This alternative combines installation of a vapor barrier with installation of a SSD system to protect a greater degree of protection against vapor intrusion in new buildings through redundancy of engineering controls. This alternative can be easily implemented during building construction. Implementation of the alternative is expected to have moderate

capital cost, and low to moderate annual cost due to required groundwater monitoring. Installation of a vapor barrier with SSD system beneath new buildings is **retained** for detailed analysis.

9.3.10 Excavate, Conduct Ex-situ Bioremediation, and Dispose of Soil On-site, and Monitor Groundwater

Ex-situ bioremediation would readily degrade petroleum hydrocarbons and fuel constituents found at RAP sites and RMP locations at the OARB. Application of this technology on-site would likely require a centralized area on the OARB where contaminated soil could be spread or piled for treatment. Creation of such an area could potentially conflict with redevelopment because ex-situ bioremediation may have to be performed for five years or more as impacted soil is discovered during infrastructure replacement.

Ex-situ bioremediation could prove advantageous if a large volume of soil impacted with petroleum hydrocarbons is excavated at one time from a RAP site or RMP location at the OARB. However, no such site or location has been identified to date.

Implementation of this alternative is expected to have low to moderate capital cost, and low to moderate annual cost. Ex-situ bioremediation is **not retained** for detailed analysis given the current uncertainty regarding the technical implementability of this technology at the OARB. However, the alternative would be considered for detailed analysis in the future if site conditions warrant evaluation of this alternative.

9.3.11 Excavate and Dispose of Soil Off-site, and Monitor Groundwater if Needed

This alternative will be implemented at RAP sites or RMP locations found to have residual COCs in soil greater than site-specific remediation goals. Groundwater monitoring will be conducted at sites also found to have minor impacts to groundwater that do not warrant active measures. Excavation and off-site disposal of some quantity of contaminated soil is assumed for most RAP sites and RMP locations at the OARB, even if available data is insufficient to determine if soil contamination exists. For sites lacking environmental data, investigations will be conducted as part of the alternative to confirm the nature and extent of chemical releases to soil, if any. Excavation will not be performed if the investigations do not reveal evidence of soil contamination.

This alternative can be readily implemented. Excavation and disposal of soil off-site with no action for groundwater is expected to have low to high capital cost depending upon the volume of soil that must be managed, and low annual cost. Low to moderate annual

cost may be experienced if groundwater monitoring must be performed. This alternative is **retained** for detailed analysis.

9.3.12 Excavate and Dispose of Soil Off-site and Perform In-situ Treatment of Shallow Water-Bearing Zone and Monitor Groundwater

This alternative is similar to the one described in Section 9.3.11 in that excavation would be accomplished to remove soil impacted with COCs at concentrations greater than site-specific remediation goals or that serves as an ongoing source of contamination to groundwater. However, at the Building 991 area, soil removal coupled with groundwater monitoring may not be sufficient to adequately remediate the shallow water-bearing zone. This alternative therefore includes groundwater treatment consisting of either in-situ chemical oxidation / reduction or in-situ bioremediation to address impacted groundwater.

Soil excavation and in-situ treatment of the shallow water-bearing zone is also considered for RAP sites or RMP locations that have use histories that suggest the potential for significant chemical releases but where no sampling has been performed to assess actual environmental conditions. Such sites include the potential drum drainage area east of Building 805 and 806 and the former motor pool and salvage operations at Building 640. These sites and locations will be investigated and not all remedial actions included in this alternative will be performed if impacts to soil and groundwater are less than those presumed and do not require remediation based upon comparison with site-specific remediation goals and protocols outlined in the RMP.

Soil excavation and in-situ treatment of the shallow water-bearing zone can be readily implemented. This alternative is expected to have moderate to high capital cost depending upon the impacts to soil and groundwater discovered, and low to moderate annual cost. This alternative is **retained** for detailed analysis.

9.3.13 Excavate, Conduct Ex-situ Immobilization, and Dispose of Soil Off-site, and Monitor Groundwater

Ex-situ immobilization is considered solely for the tarry residue at the former ORP / Building 1 area because this material may be acidic and contain high concentrations of lead that could exceed TCLP standards. It is assumed that the Army will complete demolition of Building 1 to allow access for excavation and removal of tarry residue and potentially impacted soil. Ex-situ immobilization would only be performed if a variance from LDR treatment standards could be obtained and off-site permitted waste management facilities are willing to accept the stabilized tarry residue for land disposal.

Without a variance, underlying hazardous constituents in the tarry residue may require that this material be incinerated to meet RCRA regulations. Incineration of the tarry residue is likely to be cost prohibitive and may necessitate that the untreated material be left in-place at the OARB, which would severely restrict redevelopment opportunities for the OARB.

Implementation of this alternative is expected to have high capital cost, and low annual cost. Ex-situ immobilization alternative is **retained** for detailed analysis only for the tarry residue at the former ORP / Building 1 area.

9.4 SUMMARY OF RETAINED REMEDIAL ALTERNATIVES

Listed below are remedial alternatives that undergo detailed analysis in Section 10.

- No action for soil and groundwater.
- Institutional controls.
- Monitored natural attenuation.
- Perform chemical oxidation / reduction in shallow water-bearing zone and monitor groundwater.
- Perform in-situ bioremediation in shallow water-bearing zone and monitor groundwater.
- Install vapor barrier beneath new building and monitor groundwater.
- Install vapor barrier with sub-slab depressurization system beneath new building and monitor groundwater.
- Excavate and dispose of soil off-site, and monitor groundwater as needed.
- Excavate and dispose of soil off-site and perform in-situ treatment of shallow water-bearing zone and monitor groundwater.
- Excavate, conduct ex-situ immobilization, and dispose of soil off-site, and monitor groundwater.

Application of the above alternatives to RAP sites and RMP locations at the OARB is intended to be conservative because environmental conditions at some RAP sites and

RMP locations have not been sufficiently defined. For such sites and locations, additional investigation or inspection during redevelopment activities will be conducted. In the event that these additional site characterization activities do not reveal evidence of soil or groundwater impacts, the selected remedial alternative for a given site or location may not be fully implemented.

Table 9-3 provides a summary of key parameters for remedial actions on a location specific basis. Potentially applicable remedial action alternatives developed in this section were identified for each of the RAP sites and RMP locations, based on available site-specific information. Estimated quantities for the known environmental issues were used to develop location specific cost estimates. The cost estimates are one component of the detailed analysis discussed in Section 10.

10. DETAILED ANALYSIS OF ALTERNATIVES

Section 9 describes the remedial alternatives that have been retained for consideration in this RAP. Consistent with the NCP at 40 CFR §300.430(e)(9), a detailed analysis of these alternatives has been conducted in Section 10 to identify the remedial alternative that is selected for implementation at each identified chemical release location, and suspected release locations, at the OARB property being transferred to OBRA. The detailed analysis consists of an assessment of individual alternatives against each of nine evaluation criteria and a comparative analysis that focuses upon the relative performance of each alternative against those criteria. All alternatives selected for implementation at the identified RAP sites and RMP locations at the OARB must meet the following two "Threshold Criteria:"

Threshold Criteria:

- Provide short- and long-term protection of human health and the environment from unacceptable risks posed by the hazardous substances released into the environment.
- Comply with ARARs, unless the circumstances for a waiver apply. Site-specific ARARs are identified in Table 6-1.

Besides Threshold Criteria, five "Balancing Criteria" and two "Modifying Criteria" must be considered when selecting remedial alternatives to be implemented. Balancing and Modifying Criteria consist of the following:

Balancing Criteria:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria:

- State acceptance
- Community acceptance

Balancing Criteria are used to select the remedial alternatives from those that meet the Threshold Criteria. Modifying Criteria further shape the selected alternatives by taking into account the concerns of state agencies and the public. The following six factors must be taken into account when preparing a RAP under Section 25356.1 of Chapter 6.8 of the California HSC:

- Overall protection of human health and the environment
- Compliance with federal and state requirements
- Reduction of toxicity, mobility, and volume through treatment
- Long-term effectiveness and permanence
- Cost effectiveness
- Short-term effectiveness

Remedial alternatives for OARB locations have also been evaluated against these six factors.

Tables 10-1 through 10-9 summarize an analysis of individual, general remedial action alternatives against each of the nine evaluation criteria specified in the NCP and the six factors specified under the California HSC. This assessment is general in that the alternative itself is compared against evaluation criteria and does not incorporate site-specific information. Remedial action alternatives are then assembled as appropriate at specific RAP sites and RMP locations. Tables 10-11 through 10-31 compare the No Action alternative and the site-specific alternatives that could be applicable to the RAP sites or RMP locations to the NCP and California HSC criteria. The results of the comparative analysis of remedial alternatives for RAP sites and RMP locations are summarized in Tables 10-11 through 10-31. These tables also indicate the selected remedial action alternatives.

Table 10-32 presents the present worth of total estimated costs of the selected remedial alternatives. Section 10.1 describes the manner in which costs of remedial alternatives were estimated for purposes of this RAP. Discussion of the selected remedial alternatives is presented in Sections 10.2 and is organized by RAP sites and RMP Implementation Area, which includes RMP locations.

10.1 REMEDIAL ALTERNATIVE COST ESTIMATION

Costs presented in this RAP were prepared by a detailed cost estimating approach that follows guidance jointly prepared by U.S. EPA and ACE (2000e). Detailed estimating is often referred to as "bottom up" estimating because costs are built on an item-by-item basis. Bottom up estimating relies upon quantity take-offs and assembled unit cost information. ACE (1999b) states that detailed estimating is the most accurate methodology of the approaches principally used to estimate remediation costs. Spreadsheets with line item costs supporting the summary costs presented in Table 10-32 have been prepared. The spreadsheets containing supporting cost information are voluminous and are not included in the RAP. Pertinent design assumptions, key cost factors, and assumptions are discussed in this section.

10.1.1 Design Criteria Assumptions

Detailed cost estimating requires that the environmental conditions at a site be defined, or reasonably assumed, so that a remedy can be conceptually designed and costs of the key items that comprise the remedy can be generated. Table 10-32 and the following sections summarize the key design assumptions (e.g., volumes of impacted soil) that govern the estimated costs of remedial alternatives presented in this RAP. Although many of the assumptions are subject to uncertainty, available data on the nature and extent of chemical releases that have been identified at the OARB provide reasonable assurance that the chosen remedial alternatives can be implemented within the cost ranges estimated herein and will be protective of human health and the environment. Most releases at the OARB involve relatively small quantities of petroleum hydrocarbons that have locally impacted soil only.

Conditions that may be encountered at the various RMP locations are not expected to differ greatly. U.S. EPA and ACE (2000e) state the following regarding the quality of cost estimates prepared in a RAP or FS:

> During the FS, cost estimates are developed for each remedial action alternative for comparison purposes. The accuracy of these estimates is linked to the quality of the RI data, which helps define the scope of each alternative. Because the RI/FS cannot remove all uncertainty no matter how good the data may be, the expected accuracy of cost estimates during the FS is less than that of estimates developed during the later stages of the Superfund process.

U.S. EPA and ACE (2000e) expects cost estimates prepared as part of the "detailed analysis of alternatives phase of the FS" to have an accuracy of –30 to +50 percent. Cost estimates presented in this RAP were generated with this accuracy range as a goal. Accordingly, the selected remedial alternatives and their associated estimated present worth of total costs are intended to be conservative to account for the uncertainty regarding environment conditions at RAP sites and RMP locations. As such, estimated costs, particularly for the RMP Implementation Area, have been developed to bracket plausible environmental conditions. As summarized in Table 10-32, actual costs may be lower than those estimated for selected remedial actions when environmental conditions at each chemical release location are evaluated following completion of Phase II investigations or in accordance with the RMP during redevelopment.

10.1.2 Direct and Indirect Costs of Remedial Alternatives

Costs associated with implementing remedial actions at specific RAP sites have been allocated to those sites by the site-specific alternatives and are referred to herein as direct costs. Direct costs include estimated contractor overhead and profit, design and management construction services, and contingencies. In addition to these expenditures, estimated costs have been included for the City to coordinate implementation of remedial actions with DTSC and RWQCB, conduct annual reporting, perform 5-year reviews, and supervise compliance with the RMP. These latter costs are referred to herein as indirect costs. The identified indirect costs are not assigned to individual RAP sites or RMP locations and are shown separately in Table 10-32. Indirect costs do not include premiums for insurance policies for environmental coverage or reimbursement for DTSC or RWQCB oversight of environmental restoration of the OARB. Such costs, if any, would be in addition to those stated in Table 10-32.

10.1.3 Sources of Cost Information

Unit costs included in the detailed estimates were assembled from a combination of quotations from local contractors, laboratories, vendors, and disposal facilities; EKI project experience from similar, recent San Francisco Bay Area redevelopment projects; and published cost estimating guides, including R.S. Means.

10.2 SELECTED REMEDIAL ALTERNATIVES

Selected remedial alternatives for RAP sites and RMP locations are discussed in Sections 10.2.1 and 10.2.2, and are summarized in Tables 10-11 through 10-31.

10.2.1 RAP Sites

Selected remedial actions for RAP sites are described below.

10.2.1.1 Former ORP / Building 1 Area

The selected remedial action for the tarry residue at the former ORP / Building 1 area is to excavate and neutralize, as needed, the pH of the material with lime, fly ash, or other appropriate binders. The addition of lime, fly ash, or other appropriate binders would also aid in stabilizing high concentrations of lead that are found in the tarry residue. It is assumed that the Army will complete demolition of Building 1 to allow access for excavation and removal of tarry residue and potentially impacted soil. Approval of the RAP will constitute authorization pursuant to 40 CFR §270.85 and other applicable federal or State of California laws and regulations to store temporarily and to treat on-site the tarry residue as needed to facilitate off-site transport and disposal site acceptance of the waste material.

It is assumed that the stabilized material would be disposed as a RCRA hazardous waste at an off-site permitted RCRA Subtitle C waste management facility. To minimize the amount of material that must be treated and disposed, effort would be made to segregate the relatively clean fill that overlies the tarry residue. The overburden would be reused as fill if testing indicates it does not contain COCs greater than site-specific remediation goals. Five years of groundwater monitoring is included in this remedial action.

The viability of this alternative depends upon obtaining a variance from LDR treatment standards for PAHs, PCDDs, and PCDFs in the tarry residue. Without a variance, the tarry residue may have to be incinerated to achieve LDR treatment standards for these underlying hazardous constituents. Incineration of the tarry residue is likely to be cost prohibitive and may necessitate that the untreated material be left in-place at the OARB, which would severely restrict redevelopment opportunities for the OARB. At 40 CFR 268.44, U.S. EPA has established variances for remediation waste in response to this particular sort of dilemma. These variances apply if treatment to meet LDR standards would discourage aggressive remediation or would require incineration of large volumes of contaminated soil. Both of these circumstances pertain to the tarry residue at the former ORP / Building 1 area. An application for a variance from LDR treatment requirements has been submitted to the U.S. EPA (United States Department of Defense, Department of the Army, 2002).

10.2.1.2 VOCs in Groundwater at Eastern End of Building 807

Residual VOCs in groundwater at this site consist of vinyl chloride, cis-1,2-DCE, trans-1,2-DCE, TCE, and 1,1,2,2-tetrachloroethane. Vinyl chloride and cis-1,2-DCE are capable of being degraded aerobically by in-situ bioremediation, but TCE and 1,1,2,2-tetrachloroethane are more recalcitrant to this treatment process because of the greater number of chlorine atoms on these compounds. Consequently, in-situ chemical oxidation / reduction is selected as the remedial action for VOCs in groundwater at the eastern end of Building 807. Treatability studies will be conducted to establish the types and amounts of oxidants or reductants required and the approximate grid spacing of DPT injection points across the surface area of the shallow water-bearing zone impacted at this site.

10.2.1.3 VOCs in Groundwater Near Buildings 808 and 823

Vinyl chloride is the primary COC in groundwater at this site. In-situ bioremediation of vinyl chloride in groundwater is well demonstrated. Other remedial actions evaluated for VOCs at this site consist of the use of vapor barriers alone or in combination with SDD beneath new buildings that may be constructed over the area with impacted groundwater. While the use of vapor barriers and SSD are expected to protect human health and the environment and comply with ARARs, in-situ bioremediation was selected instead of these alternatives because of the preference for treatment expressed in the NCP and California HSC. In-situ bioremediation will be accomplished by injecting ORC into the subsurface with DPT.

10.2.1.4 VOCs in Groundwater Near Building 99

Vinyl chloride and cis-1,2-DCE are the predominant COCs in the shallow water-bearing zone near Building 99. Although detected vinyl chloride and cis-1,2-DCE concentrations are less than the remediation goals (Table 7-11), the source(s) of these contaminants to groundwater was never identified. Treatment of the shallow water-bearing zone is warranted to eliminate residual quantities of vinyl chloride and cis-1,2-DCE that are likely present in the capillary fringe or otherwise in unidentified impacted soil at or near the groundwater surface, which could allow these COCs to desorb from soil in the future and cause increases of vinyl chloride concentrations in groundwater. Further, the presence of vinyl chloride and cis-1,2-DCE in groundwater or future concentration increases could interfere with planned redevelopment in the area near Building 99 if not addressed. Both vinyl chloride and cis-1,2-DCE are amenable to aerobic degradation by microorganisms. The selected alternative for this site is in-situ bioremediation with ORC to remove or significantly reduce remaining COC quantities prior to redevelopment.

10.2.1.5 Benzene and MTBE in Groundwater Near Former USTs 11A/12A/13A

Impacted soil that may act as a source of petroleum hydrocarbons and fuel constituents to groundwater will be addressed by excavating contaminated soil in the vicinity of the former location of the tanks. For cost estimating purposes, it is assumed that 170 cy of non-impacted overburden will be removed and stockpiled for reuse; 110 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility. Benzene and MTBE remaining in the shallow water-bearing zone will be treated by in-situ bioremediation using ORC.

10.2.1.6 Building 991 Area

Soil and groundwater at the Building 991 are also contaminated by petroleum hydrocarbons. Contaminated soil that may continue to leach petroleum hydrocarbons to groundwater will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility. It is assumed that 500 cy of petroleum hydrocarbon-containing soil necessitate removal at the Building 991 area. Residual petroleum hydrocarbons in groundwater will be addressed by in-situ bioremediation using ORC.

10.2.1.7 Building 99

Building 99 is categorized as a RAP site because of its long industrial use history that includes prior ship manufacturing, metalworking, and equipment repair. Only limited testing that has been done inside the building. This testing has not revealed evidence of significant chemical releases. However, the possibility remains that contaminated soil may be present under Building 99. Groundwater in the Building 99 area has been extensively investigated, and VOC and petroleum hydrocarbon impacts to the shallow water-bearing zone are generally well characterized. Additional groundwater contamination attributable to Building 99 is not anticipated. Required remedial actions, if any, are likely to consist of excavating soil with COCs greater than site-specific remediation goals after Building 99 has been demolished. For cost estimating purposes, it is assumed that 400 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2 RMP Implementation Area

The RMP Implementation Area is not as well characterized as RAP sites. It is not known if chemical releases have occurred at many of the identified RMP locations included within the RMP implementation area. However, the fact that information within the

RMP Implementation Area is incomplete does not interfere with selecting remedial actions that are sufficient to address any impacts that may be found or developing protocols in the RMP for proper implementation of these remedies. The success of these remedies and the manner in which they have been implemented has been demonstrated at other properties in the San Francisco Bay Area that have undergone redevelopment. The use history and data compiled for the OARB provide further confidence that the RMP approach is appropriate for environmental restoration of the OARB. Review of available information yields a strong understanding of the types of COCs and manner of potential releases that can be expected at RMP locations. In the event that the nature and extent of the releases at RMP locations are found to differ significantly from the conditions assumed in the RAP, the appropriateness of selected remedial alternatives will be re-evaluated for such specific RMP locations in accordance with the RMP. If the response measures contained in the RAP are inappropriate for newly identified releases at RMP locations, the City will consult with DTSC to determine appropriate actions. Amendment of the RAP may be required to select other appropriate remedies.

10.2.2.1 Washracks, Sumps, Oil/Water Separators, and Miscellaneous Operations

These RMP locations are divided into four subgroups depending upon the environmental conditions known or suspected to exist at the RMP locations as discussed in Section 4.4.4.1. A single remedial alternative cannot be selected that is appropriate for all RMP locations because of these varying conditions. Therefore, the range of potential remedial alternatives evaluated (Table 10-17) for washracks, sumps, oil/water separators, and miscellaneous operations provide responses that are adequate for the four subgroups. Inspection and sampling requirements during redevelopment to confirm the appropriate remedial actions for each washrack, sump, oil/water separator, and miscellaneous RMP location are provided in the RMP. The RMP also specifies the protocols for implementing remedial actions at these RMP locations and performing confirmation testing to verify adequate remediation has been achieved.

Site-specific cost estimates were not generated for washracks, sumps, oil/water separators, and miscellaneous operations. The cost estimates presented in Table 10-17 are meant to represent expenditures typical of those that will be incurred to remediate the RMP locations based on available analytical results and experience with similar remedial actions at other properties in the San Francisco Bay Area. While actual costs will vary by RMP location, it is believed that the overall expenditures to address washracks, sumps, oil/water separators, and miscellaneous operations are reasonably captured in the sum of costs presented in Table 10-17. Remedial actions for each of the four subgroups in this category are discussed in Sections 10.2.2.1.1 through 10.2.2.1.4.

10.2.2.1.1 Locations Requiring Removal of an Existing Structure

This subgroup consists of seven RMP locations (Table 4-2) where the oil/water separator, washrack, or another type of structure (e.g., hydraulic lift) still remains and must be removed during redevelopment. It is assumed for cost estimating purposes that an average of 50 cy of debris and contaminated soil will be removed at each of these RMP locations and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.1.2 Locations Requiring Additional Characterization

This subgroup (Table 4-2) consists of washracks, sumps, oil/water separators, and miscellaneous operations where it is not known if soil and groundwater have been impacted. These RMP locations will be inspected and sampled for potential contamination during infrastructure replacement or during new building construction as outlined in the RMP. For cost estimating purposes, it is assumed that additional characterization will identify an average of 50 cy of impacted soil that must be removed at each of these RMP locations and disposed as non-RCRA hazardous waste at an off-site permitted facility. Excavation will not be performed if no contaminated soil is identified.

10.2.2.1.3 Locations Potentially Requiring Removal of Impacted Soil During Redevelopment

Available data or use histories for this subgroup (Table 4-2) suggest the presence of residual contaminated soil. It is assumed that an average of 50 cy of contaminated soil will be removed at each of these RMP locations and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.1.4 Locations With No Currently Identified Environmental Issues

The RMP locations in this subgroup (Table 4-2) are not expected to be contaminated because they have been adequately characterized and no COCs were detected (e.g., former indoor firing range at Former Building 682, pesticide storage sheds on northwest of Building 840) or their use histories do not suggest the potential for significant chemical releases of (e.g., kitchen grease traps, household incinerators). Although no impacts necessitating remediation are expected, chemical releases are still considered to have potentially occurred at these RMP locations and will be inspected in accordance with the RMP during redevelopment to confirm no contamination exists at these RMP locations.

10.2.2.2 Tanks

Similar to washracks, sumps, oil/water separators, and miscellaneous operations, the types of remedial actions to be performed at tank locations are predicated upon the environmental conditions known or suspected to exist at these RMP locations. Three subgroups of tank locations have been identified.

10.2.2.2.1 Tank Locations Potentially Requiring Removal of an Existing Tank

Removal of any USTs existing at the OARB will be performed during infrastructure replacement or during new building construction. Review of historical records indicates that 13 heating oil USTs may still remain at the OARB. For cost estimating purposes, it is assumed that one tank and an average of 50 cy of impacted soil will be removed and disposed at an off-site permitted facility at each RMP location where a tank must be excavated.

10.2.2.2.2 Former Tank Locations Potentially Requiring Removal of Impacted Soil During Redevelopment

Soil containing petroleum hydrocarbons exist at many former tank locations. Table 4-3 lists the former tank locations believed to have petroleum hydrocarbons in soil based upon the evaluation conducted by ITSI (2001). While concentrations of petroleum hydrocarbons in soil at these RMP locations may be less than the Army's Fuel Storage Tank Sites Cleanup Levels, residual petroleum hydrocarbons may still pose odor or other nuisances if the impacted soil is excavated during redevelopment activities. The removal of such soil is expected to result in higher disposal costs because the contaminated soil must be managed at a permitted off-site facility instead of being used as clean fill. Consequently, protocols have been established in the RMP for management of such soil. It is assumed that an average of 50 cy of contaminated soil will be removed at each of these RMP locations and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.2.3 Former Tank Locations Potentially Requiring Both Removal of Impacted Soil During Redevelopment and Groundwater Monitoring

As described in Section 10.2.2.2.2, soil containing petroleum hydrocarbons exists at many former tank locations; some of these RMP locations are anticipated to require groundwater monitoring to meet regulatory closure requirements. Natural attenuation of petroleum hydrocarbons in shallow groundwater is currently being monitored at seven tank locations under RWQCB supervision. For such tank locations, it is assumed that an

average of 50 cy of contaminated soil will be removed at each of these tank locations and disposed as non-RCRA hazardous waste at an off-site permitted facility. In addition to the costs of managing contaminated soil during redevelopment, five years of groundwater monitoring and associated reporting are assumed.

10.2.2.2.4 Former Tank Locations With No Currently Identified Environmental Issues

Analytical results of confirmation soil samples at the RMP tank locations in this subgroup (Table 4-3) do not indicate that significant releases from the former tanks at these locations occurred. Although no impacts necessitating remediation are expected, these locations are still considered potential chemical release locations and will be inspected in accordance with the RMP during redevelopment to confirm no contamination exists at these locations.

10.2.2.3 Former Industrial and Chemical Handling Locations

Seven locations have been identified at the OARB where former industrial activities or chemical handling took place for which little or no subsurface environmental data are currently available. Investigations will be performed to characterize subsurface environmental conditions at these locations. Remedial actions to address soil, or soil and groundwater contamination, have been conservatively assumed at all of these locations. Actual remedial actions will depend upon investigative findings and will be implemented as part of the RMP.

10.2.2.3.1 Debris Area Near Building 99

The alternative for this location assumes that 200 cy of soil mixed with debris will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.3.2 Building 85

This alternative assumes 100 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.3.3 Building 812

This alternative assumes 100 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.3.4 Building 823

This alternative assumes 200 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.3.5 Potential Drum Drainage Area East of Buildings 805 and 806

Chlorinated solvent releases similar to those that took place at the eastern end of Building 807 are assumed for the potential drum drainage area east of Buildings 805 and 806. For cost estimating purposes, it is assumed that the presence of chlorinated solvents render 250 cy of excavated soil as RCRA hazardous waste that is disposed at an off-site permitted facility. Residual VOCs in 2,800 sf of the shallow water-bearing zone are addressed through in-situ chemical oxidation / reduction.

10.2.2.3.6 Former Motor Pool and Salvage Operations at Building 640

The remedial action for this location assumes that soil and shallow groundwater have been impacted by petroleum hydrocarbons. For cost estimating purposes, it is assumed that a total of 250 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility. In addition, in-situ bioremediation of approximately 6,300 sf of the shallow water-bearing zone is assumed to be necessary.

10.2.2.3.7 Benzidine at Former Used Oil Tank 21

This alternative assumes 50 cy of contaminated soil will be excavated and disposed as non-RCRA hazardous waste at an off-site permitted facility.

10.2.2.4 Historical Spills and Stains

Figure 4-14 depicts the locations where spills and stains have been historically observed or noted. Given the use history of the OARB, most of these releases likely involved petroleum hydrocarbons associated with diesel fuel or motor oil. Historical spills and stains are considered to be a basewide RMP issue. As a consequence, soil excavated during new construction will be inspected for contamination. Protocols for inspecting and managing contaminated soil during and after redevelopment are specified in the RMP.

10.2.2.5 Lead in Soil Around Buildings

The EIR contemplates demolition of buildings and improvements at the OARB as part of redevelopment. Planned demolition includes those buildings where LBP is known or suspected to be present in shallow soil around the structures (Figure 4-15). Testing near these buildings will be conducted in exposed soils adjacent to painted structures built on or before 1978 to determine if lead concentrations in shallow soil are greater than the site-specific remediation goal of 750 mg/kg, as provided in Table 7-11.

Soil management protocols of the RMP will be followed. Excavated soil with representative total lead concentrations less than 350 mg/kg may be reused anywhere on-site provided such reuse complies with the risk-based remediation goals in Table 7-11 and applicable law and regulations. Excavated soil with representative total lead concentrations between 350 mg/kg and the remediation goal of 750 mg/kg will be disposed at an off-site permitted waste management facility unless specifically approved by DTSC for reuse at the OARB or upon termination of the requirements of HSC §25157.8. Soil with representative lead concentrations exceeding the site-specific remediation goal of 750 mg/kg will be excavated and disposed at an off-site permitted waste management facility. Other requirements for managing shallow soil known or suspected to contain LBP and other COCs at the OARB are incorporated into the RMP.

10.2.2.6 Former PCB-Containing Transformers and Equipment Locations

Electrical equipment at the OARB that still contains PCBs will be removed from service and managed in accordance with TSCA regulations prior to building demolition. Outdoor areas where transformers were located will also be inspected and sampled for the presence of PCBs in concrete, asphalt, and underlying soil as specified in the RMP before improvements are razed. Soil containing PCBs greater than remediation goals will be excavated and disposed at an off-site permitted facility. Management of PCB-containing equipment and media contaminated by PCBs is also subject to U.S. EPA requirements under TSCA.

10.2.2.7 Storm Drains and Sanitary Sewers

Soil contamination associated with existing storm drains and sanitary sewers, as described in the Army reports, can be adequately addressed through the RMP as part of infrastructure replacement. Removing contaminated soil will also serve to remediate minor localized impacts to groundwater by eliminating the source of COCs to the shallow water-bearing zone. Monitored natural attenuation will be relied upon to degrade low

concentrations of petroleum hydrocarbons or VOCs that may remain in shallow groundwater at these locations.

Investigation of sediment inside the storm drains will be conducted in advance of infrastructure replacement. The purpose of this investigation is to determine if significant quantities of contaminated sediment exists in the storm drains. Interim remedial actions will be performed if COC-containing sediment is discovered. Such actions may consist of flushing segments of storm drain line with water to remove and capture the contaminated sediments for disposal at an off-site permitted facility. Alternatively, cement grout or similar means can be used to seal the ends of storm drain branch lines that are collapsed or otherwise can be removed from service without exacerbating flooding concerns.

10.2.2.8 Railroad Tracks

Approximately 26 miles of railroad track remain at the OARB. Like storm drains and sanitary sewers, existing railroad tracks at the OARB will be removed or replaced during redevelopment. One of the primary functions of the Port Development Area is to act as a new joint intermodal terminal that will load and unload container cargo from trucks and railroad cars for transport to and from destinations across the United States.

Besides preliminary sampling conducted during the Phase II investigations, protocols for inspecting and testing potentially contaminated railroad track ballast or sub-ballast during redevelopment have been established in the RMP. Sub-ballast found to contain COCs greater than remediation goals will be excavated for disposal at an off-site permitted facility or, if specifically approved by DTSC, may be incorporated into the on-site railroad beds upon which new tracks will be laid and covered with clean ballast.

10.2.2.9 Marine Sediments

COC impacts to marine sediments near storm drain outfalls in the Oakland Outer Harbor on former BRAC Parcels 2 and 3 have been identified by the Army. Marine sediments at Outfall 4 are defined to be part of former BRAC Parcel 1 and, thus, are not included in this RAP. The Army (Harding ESE, 2002) concluded that sediments at Outfalls 5 through 7 are "are unlikely to result in unacceptable adverse effects on aquatic or wildlife receptors." No further action is proposed for Outfalls 5 through 7.

The Port of Oakland intends to fill 26 acres to provide additional terminal capacity and create two berths in the Oakland Outer Harbor as outlined its Seaport Plan for 2020 (Harding ESE, 2002). The Port of Oakland berth expansion project will cover impacted

sediments. Thus, no ecologically significant exposures to the impacted sediments will remain upon completion of the Port of Oakland's berth construction project. Implementation of remedial actions for marine sediments on former BRAC Parcels 2 and 3 will be coordinated with the Port of Oakland's berth construction project.

10.3 SUMMARY OF RECOMMENDED REMEDIAL ACTIONS

The results of the above detailed analysis determine the remedial alternatives that are recommended for implementation at portions of OARB to be transferred to OBRA via an EDC. Section 10.2 presents the detailed analysis of alternatives against NCP and state criteria and ends with a summary of recommended remedial actions at identified RAP sites and RMP locations. The recommended remedial actions for identified RAP sites and RMP locations and areas are presented in Table 10-32, along with estimated remediation costs. An implementation schedule is discussed in Section 11 for the recommended remedial actions, including implementation of the RMP as phased redevelopment occurs.

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11. REMEDIAL ACTION IMPLEMENTATION SCHEDULE

The implementation schedule for the selected remedial actions at the RAP sites and RMP locations at the OARB, as summarized in Section 10, will conform to the overall redevelopment schedule outlined in OBRA's Amended EDC Application, dated 29 November 2001 (OBRA, 2001a) (the "EDC Application"). OBRA's development plan anticipates a phased approach to the redevelopment of the properties at OARB to be transferred to OBRA under the EDC. The phased approach allows the precise timing and scale of the development to remain flexible to local market conditions. The EDC Application outlines a development plan that extends ten years after conveyance.

The Army's FOSET funding criteria generally require that environmental remediation be implemented within five years after conveyance of the OARB properties under the EDC, i.e., Army funding for remedial actions should be expended within five years of transfer. OBRA's plans to complete all remedial actions at RAP sites within five years in accordance with Army requirements outlined in Section 11.1. Thus, the available funding from the Army will be expended first on the most significant sites requiring remediation. Remaining funding from the Army will be expended on the RMP locations encountered in this period during infrastructure repair and replacement, which, for example, will address known and discovered contamination near existing storm drains and sanitary sewers. Extensions of the Army's funding obligations will also be sought to complete RMP implementation activities through the OARB redevelopment program.

The RMP locations identified in this RAP are low threat, potential COC release areas, primarily consisting of former base areas where petroleum hydrocarbons, associated constituents, and possibly other COCs such metals and SVOCs may have been used, stored, or released. Anticipated environmental conditions at these locations are comparable to those commonly encountered and managed during re-development construction activities at former industrial sites, in the Bay Area and around the country. RMP locations at OARB are not known to be or are not expected to become RAP sites, i.e., such conditions would often not be remediated under Section 6.8 of the HSC when encountered at typical construction sites around the Bay Area. Many RMP locations are simply former UST or AST locations at the OARB that have already been closed or are in corrective action monitoring by RWQCB. In general, these locations are likely to be relatively lower cost sites to manage and remediate, if needed, than the identified RAP sites. Most RMP locations will involve simple removal actions for TPH-contaminated or metal-contaminated soils, abandoned pipelines, oil-water separators, and similar subsurface or shallow buried structures. Many of these RMP locations are located within the PDA, and the Port of Oakland has found, in similar areas along the Oakland Harbor,

that such encountered structures can be addressed cost-effectively and with great efficiency during redevelopment. The schedule for completing implementation of investigation and remediation activities, if necessary, at RMP locations is discussed in Section 11.2.

11.1 SCHEDULE FOR RAP SITES

As discussed in Section 10, there are seven identified RAP sites at which the selected remedial actions will be implemented. The City will implement the selected remedies for all seven RAP sites and, as noted below, for particular RMP locations within five years after conveyance. The City will evaluate all existing data in conjunction with the recently obtained Army and OBRA Phase II investigation results, in consultation with DTSC, to determine the scope of additional site characterization for the RAP sites. RMP locations for which additional data from Phase II investigations are available will also be reviewed with DTSC following transfer to identify RMP locations for consideration of prioritization for investigation and remediation during the initial five year period post-transfer, or elevation to RAP site status as discussed in the RMP. The City will obtain DTSC's approval on the remedial design at each of these RAP sites prior to implementation of the remedies selected in this RAP. The City will continue to provide public participation activities (e.g., issue fact sheets, hold community meetings, and forward project documents to repositories) during the design and implementation phases of the remedial actions for the RAP sites.

Three of the RAP sites, VOCs in Groundwater near Buildings 808 and 823, VOCs in Groundwater near Building 99, and the former ORP / Building 1 area are within the planned GDA. The remaining RAP sites are outside of the planned GDA.

Buildings 808 and 823 are within the area slated the first phase of development of the GDA. Therefore, OBRA anticipates remedial actions for the VOCs identified in groundwater in this area to be initiated as a first priority after conveyance. The selected remedial action is in-situ bioremediation of COCs in groundwater, which will have minimal surficial impacts after the injection of the chemicals in to the subsurface. Monitoring wells will be protected during subsequent development activities.

The former ORP / Building 1 area and VOCs in Groundwater near Building 99 RAP sites are also within the GDA, but development of this central portion of the GDA is planned as a later phase of redevelopment, following development of areas north of West Grand Avenue, and east of Maritime Street according to the EDC Application. This will allow remedial actions at these areas to be initiated and performed within the first one to three

years after conveyance, with remedial actions to be completed before the end of Year Five after conveyance, exclusive of any longer-term monitoring or maintenance required. With the complexity of issues surrounding the former ORP / Building 1 area, including demolition, excavation, disposal of residuals with an LDR variance, and site restoration, a slightly later starting date for construction within this period may be required to effectively plan implementation of remedial actions in this area.

The remaining RAP sites (VOCs in Groundwater at the Eastern End of Building 807, Benzene and MTBE near Former USTs 11A/12A/13A, Building 991 Area, and Building 99) are not within the GDA. The investigations and remedial actions for these sites will likely be initiated within the first two years after conveyance, such that remedial actions can be substantially completed prior to the end of Year Five after conveyance. Most of these sites also incorporate in-situ groundwater treatment, and several include potential soil excavation. These activities will be completed in a manner to coordinate with the initiation of redevelopment activities in their respective areas.

11.2 SCHEDULE FOR RMP LOCATIONS

The RAP site areas, before and after remediation, and the remainder of the OARB properties included in the early transfer to OBRA under the EDC will constitute the RMP Implementation Area. The RMP will be implemented within the RMP Implementation Area until such time, and at such locations, as remediation to unrestricted, health protective levels is accomplished or termination of the RMP is achieved with concurrence of the DTSC as provided in Section 5 of the RMP.

Remediation in the RMP Implementation Area will occur in phases consistent with redevelopment projects, and the RMP will remain in effect even after redevelopment until such time as DTSC is requested to approve, and does approve, such locations for unrestricted future uses. The City will implement the RMP protocols and removal and cover remedies for the RMP locations within ten years after the conveyance, with the schedule linked to both the redevelopment program and the ongoing availability of the Army's environmental remediation funding.

A major component of the remedial actions associated with RMP locations is directly related to the infrastructure development, as the process of removing, replacing, or installing new roads and subsurface utilities may reveal the potential environmental impacts within the RMP Implementation Area at the OARB. The applicable remedial actions associated with known or encountered environmental impacts will be implemented in accordance with the procedures identified in the RMP. For property

areas where redevelopment is scheduled for later phases, OBRA's EDC Application states that the infrastructure development will be accelerated so as to be completed with the five-year period post-conveyance. Thus, although complete development of the properties may occur after Year Five following conveyance, the main infrastructure (roads and utilities) will be in place for the future buildout, and associated remedial activities for many RMP locations will, therefore, be completed by the City prior to the end of the fifth year after conveyance. DTSC will require the City to comply with the RMP in subsequent redevelopment activities as actual site preparation and construction occurs on all portions of the transferred property.

Implementing the protocols of the RMP at all RMP locations within the ten years provided for the EDC redevelopment plan is not only efficient, it is consistent with the planned remediation cost-cap environmental insurance policy to be purchased as part of the conveyance from the Army. Thus, if significant new releases of COCs are discovered at RMP locations, this schedule will allow claims for insured liabilities under the available insurance coverages funded by the Army.

This schedule is intended to allow the overall development to proceed in accordance to local market conditions but still complete major environmental remedial actions by the end of Year Five, in accordance with Army funding requirements, and all remaining RMP locations by the end of Year Ten.

12

12. NONBINDING ALLOCATION OF RESPONSIBILITY

HSC Section 25356.1(e) requires the preparation of a nonbinding allocation of responsibility (the "NBAR") among all identifiable potentially responsible parties ("PRPs"). HSC Section 25356.3(a) allows PRPs with an aggregate allocation in excess of 50 percent to convene an arbitration proceeding by submitting to binding arbitration before an arbitration panel. If PRPs with over 50 percent of the allocation convene arbitration, then any other PRP wishing to do so may also submit to binding arbitration.

The sole purpose of the NBAR is to establish which PRPs will have an aggregate allocation in excess of 50 percent and can therefore convene arbitration if they so choose. The NBAR, which is based on the evidence available to DTSC, is not binding on anyone, including PRPs, DTSC, or the arbitration panel. If a panel is convened, its proceedings are de novo and do not constitute a review of the provisional allocation. The arbitration panel's allocation will be based on the panel's application of the criteria spelled out in HSC Section 25356.3(c) to the evidence produced at the arbitration hearing. Once arbitration is convened, or waived, the NBAR has no further effect, in arbitration, litigation or any other proceeding, except that both the NBAR and the arbitration panel's allocation are admissible in a court of law, pursuant to HSC Section 25356.7 for the sole purpose of showing the good faith of the parties who have discharged the arbitration panel's decision.

DTSC sets forth the following preliminary nonbinding allocation of responsibility for the OARB:

> The Army is currently responsible for the investigation and cleanup activities within the area covered in this RAP, and currently has an aggregate allocation of liability in excess of the 50 percent level required to convene arbitration pursuant to HSC Section 25356.3(a). However, the Army and OBRA / ORA are entering into an Environmental Services Cooperative Agreement for which the Army will provide funds for OBRA's performance of environmental remediation activities at the site. As of the execution of this Agreement and completion of the conveyance, OBRA / ORA would have the aggregable allocation of liability in excess of the 50 percent level required to convene arbitration pursuant to HSC Section 25356.3(a).

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