# Final
# Operable Unit Carbon Tetrachloride Plume Groundwater Remedial Investigation/ Feasibility Study
# Former Fort Ord, California

## Volume III – Feasibility Study

Prepared for

**United States Army Corps of Engineers**
Sacramento District
1325 J Street
Sacramento, California 95814-2922

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Margaret Stemper
Margaret Stemper
Senior Engineer

By NLH with permission

Michael Taraszki, PG, CHG
Principal Hydrogeologist

CERTIFIED HYDROGEOLOGIST
MICHAEL D. TARASZKI
No. 586
EXP. 12/06
STATE OF CALIFORNIA

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MACTEC Engineering and Consulting, Inc.
600 Grand Avenue, Suite 300
Oakland, CA 96510 - (510) 451-1001

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# Operable Unit Carbon Tetrachloride Plume Groundwater Remedial Investigation/Feasibility Study
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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| atm-m/mol | atmosphere-millomol |
| ACL | aquifer cleanup level |
| AE | average exposure |
| ARAR | Applicable or Relevant and Appropriate Requirement |
| Army | U.S. Department of the Army |
| BACT | Best Available Control Technology |
| bgs | below ground surface |
| C | degree Celsius |
| Cal/EPA | California Environmental Protection Agency |
| CCR | California Code of Regulations |
| CDFG | California Department of Fish and Game |
| CFR | Code of Federal Regulations |
| CNPS | California Native Plant Society |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CT | carbon tetrachloride |
| COC | chemicals of concern |
| COPC | chemical of potential concern |
| COR | close-out reports |
| 1,2-DCA | 1,2-dichloroethane |
| DO | dissolved oxygen |
| DNAPL | dense nonaqueous phase liquid |
| DTSC | Department of Toxic Substances Control |
| EOS | Edible Oil Substrates |
| EPA | (United States) Environmental Protection Agency |
| ESA | Endangered Species Act |
| EW | extraction well |
| FAAF | Fritzsche Army Airfield |
| FOD | frequency of detection |
| FORA | Fort Ord Reuse Authority |
| FO-SVA | Fort Ord—Salinas Valley Aquitard |
| ft/day | feet per day |
| FS | Feasibility Study |
| fy | fiscal year |
| GAC | granulated activated carbon |
| GMS | groundwater modeling system |
| GWET | groundwater extraction and treatment |
| GWETS | groundwater extraction and treatment system |
| gpd | gallons per day |
| gpm | gallons per minute |
| GWTS | Groundwater Treatment System |
| H&SC | Health and Safety Code |
| Harding ESE | Harding ESE, Inc. (formerly HLA; now MACTEC) |
| HHRA | Human Health Risk Assessment |
| HLA | Harding Lawson Associates (now MACTEC) |
| HMP | Habitat Management Plan |
| IW | injection well |
| IWS | in-well stripping |

| | |
|---|---|
| MACTEC | MACTEC Engineering and Consulting, Inc. |
| MCWD | Marina Coast Water District |
| MBUAPCD | Monterey Bay Unified Air Pollution Control District |
| MCL | Maximum Contaminant Level |
| MCLG | Maximum contaminant Level Goals |
| MEK | methyl ethyl ketone |
| MNA | monitored natural attenuation |
| mg | milligrams |
| mg/kg | milligrams per kilograms |
| mg/L | milligrams per liter |
| ml | milliliter |
| MW | monitoring well |
| NAAQS | National Ambient Air Quality Standards |
| NCP | National Contingency Plan |
| NPDES | National Pollutant Discharge Elimination System |
| NPV | net present value |
| O&M | operations and maintenance |
| OMB | Office of Management and Budget |
| ORP | oxidation/reduction potential |
| OU1 | Operable Unit 1 |
| OU2 | Operable Unit 2 |
| OUCTP | Operable Unit Carbon Tetrachloride Plume |
| PCE | tetrachloroethene |
| POTW | Publicly Owned Treatment Work |
| ppb | parts per billion |
| ppm | parts per million |
| PRB | permeable reactive barrier |
| PVC | poly-vinyl chloride |
| RA | Risk Assessment |
| RCA | Resource conservation Recovery Act |
| RI | Remedial Investigation |
| RI/FS | Remedial Investigation/Feasibility Study |
| RME | reasonable maximum exposure |
| ROD | Record of Decision |
| RWQCB | Regional Water Quality Control Board |
| SOP | standard operating procedures |
| SVA | Salinas Valley Aquitard |
| SVE | soil vapor extraction |
| TBC | to be considered |
| TCE | trichloroethene |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| TSD | treatment, storage, or disposal |
| µg/L | micrograms per liter |
| UIQ | underground injection control |
| USACE | United States Army Corps of Engineers |
| USFWS | United States Department of the Interior, Fish and Wildlife Services |
| vc | vinyl chloride |
| VOC | volatile organic compound |
| WMU | waste management unit |
| ZVI | zero valent iron |

# EXECUTIVE SUMMARY

This Feasibility Study (FS) identifies potential remedial technologies and preliminarily identifies a preferred remedial alternative to address groundwater contaminants present in three distinct aquifers within the Operable Unit Carbon Tetrachloride Plume (OUCTP) at the former Fort Ord in Monterey County, California (Plate 1). The results of this FS will be used to support the OUCTP Remedial Investigation/Feasibility Study (RI/FS) Proposed Plan and Record of Decision (ROD) that will document the results of the Remedial Investigation (RI; Volume I), Human Health Risk Assessment (HHRA; Volume II) and this Feasibility Study (FS; Volume III).

## *Objectives and Purpose*

The objectives of this FS are to (1) review the findings and recommendations presented in the RI and HHRA and summarize the results, (2) define the Remedial Action Objectives (RAOs) for cleanup of volatile organic compounds (VOCs) detected in these aquifers, and (3) describe the process used to develop, evaluate, compare and select preferred alternatives that will meet the RAOs based on the results of the RI and HHRA.

The purpose of this FS is to develop and evaluate a range of alternatives that could be implemented to remediate VOC contamination, specifically carbon tetrachloride (CT), detected in groundwater of the A-Aquifer, Upper 180-Foot Aquifer, and Lower 180-Foot Aquifers within OUCTP (Plates 2A—4B).

The development and selection of remedial alternatives require the following steps presented in this FS:

- Defining RAOs by identifying federal and State chemical-, location-, and action-specific Applicable or Relevant and Appropriate Requirements (ARARs) and specifying the contaminants and media of interest, exposure pathways, and remediation goals, so that a range of treatment and containment alternatives can be developed;
- Identifying specific remedial units (volumes or areas of media that share similar characteristics and contaminants) for which general response actions may be applied;
- Identifying potential treatment and containment technologies from the general response actions that will satisfy the RAOs for each remedial unit identified;
- Screening the technologies based on their effectiveness, implementability, and cost;

- Assembling technologies and their associated containment or treatment combinations into remedial alternatives for each remedial unit identified;

- Conducting a detailed analysis of the range of remedial alternatives developed—that vary primarily in their cost to implement, operate, and maintain, and the time required to meet the RAOs—by evaluating and comparing them based on the United States Environmental Protection Agency's (EPA's) nine Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation criteria to address the statutory requirements and preferences of EPA guidance (*EPA, 1989b*) and the National Contingency Plan (NCP); and

- Selecting a preliminarily identified preferred remedial alternative that best meets the evaluation criteria.

Each remedial action must: (1) be protective of human health and the environment, (2) attain ARARs, (3) be cost-effective, and (4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Following issuance of a final OUCTP RI/FS report and Proposed Plan for public comment, a Record of Decision (ROD) will document the selected alternative(s). Responses to comments received during the public comment period will be found in a Responsiveness Summary which is part of the ROD. Once the ROD is issued, remedial design (if necessary) will begin. During the remedial design phase, many of the uncertainties and generalities present in the FS will be resolved.

### *Definition of Remedial Action Objectives and Cleanup Levels*

The primary RAOs for OUCTP groundwater impacted by VOCs are (1) to reduce risks to human health and the environment, and (2) comply with ARARs such as federal, State, and local laws.

RAOs are established to allow the identification and screening of remedial alternatives that will achieve protection of human health and the environment consistent with reasonably anticipated land use. No ecological receptors were identified as potentially being exposed to VOCs in groundwater within OUCTP; therefore, risks to the environment were not assessed except as may occur during implementation of the alternatives.

Cleanup levels are acceptable contaminant levels that when achieved within a site, would mitigate potential risks and comply with ARARs. Aquifer cleanup levels (ACLs) were developed for OUCTP based on (1) a preliminary assessment of the ARARs; and (2) the results of the HHRA summarized in Volume II of this report. Final ARARs, compliance with ARARs, and the applicability of any waivers of

ARARs will be determined when the remedial action is selected, as described in the Proposed Plan and finalized in the ROD.

The following RAOs are proposed for groundwater within OUCTP:

- Exposure Control—Prevent the potential exposure of child and adult residents to groundwater contaminants above ACLs; and

- To the extent practicable based on technical and economic feasibility, achieve:

  --Source Control—Prevent or minimize further degradation of groundwater at the site;

  --Plume Containment—Mitigate the potential for contaminants to continue to migrate offsite; and

  --Plume Remediation—Reduce contaminant concentrations in groundwater to below ACLs.

The Proposed ACLs for each of the three aquifers in OUCTP were developed as follows:

Chemicals of Concern (COCs)—COCs were identified based on their concentration, frequency of detection, and toxicity, and an assessment of their contribution to cumulative risks as described in the HHRA;

Federal and State drinking water levels (Maximum Contaminant Levels; MCLs) were reviewed for each COC (*National Primary Drinking Water Standards* [*EPA, 2003*] and State of California Department of Health Services' *MCLs, DLRs and PHGs for Regulated Drinking Water Contaminants* [*DHS, 2004*]).

The results of the HHRA (Volume II) for OUCTP indicate that there is a potential cancer risk for a future onsite resident that uses untreated groundwater from OUCTP for drinking and household water purposes. It should be noted that groundwater from OUCTP is not currently supplied for domestic use, and in general, "exposure control" is achieved for OUCTP because the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999. Therefore, the estimated risks are based on a hypothetical "worst-case" scenario under which an individual installs a private drinking water well without authority, permit, or approval, and uses it exclusively for their drinking and household water purposes.

A hypothetical on-site resident represents the most conservative exposure scenario evaluated. Contamination in the A-Aquifer was associated with the highest estimated cancer risk (1E-05); followed by the Upper 180 Foot-Aquifer (E-06); and then the Lower 180-Foot Aquifer (2E-06). Noncancer hazards were less than 1. These cumulative risk estimates for exposure to contaminants in groundwater are within the EPA and Cal/EPA-DTSC cancer risk management range of 1 in 10,000 to 1 in 1,000,000 (or alternately 1E-4 to 1E-6), but greater than the California Environmental Protection Agency (Cal/EPA)-Department of Toxic Substances Control (DTSC's) point of departure for risk management of 1 in 1,000,000. Noncancer hazards are less than 1 in each aquifer for all receptors. Therefore, the more conservative or lower of the federal or State MCLs for each COC within the OUCTP plume were selected as ACLs because total risks estimated in the HHRA (Volume II) are within regulatory risk management ranges, and MCLs are enforceable standards for chemicals that may affect public health or the aesthetic qualities of drinking water.

### *Description of Remedial Units*

Three groundwater remedial units correspond with the plumes containing VOCs above aquifer cleanup levels (ACLs) in the A-Aquifer, Upper 180-Foot Aquifer, and Lower 180-Foot Aquifer. The results of the RI indicated the source of CT contamination is no longer in contact with groundwater. Therefore, contamination throughout OUCTP is in the aqueous phase, and the plumes are no longer attached to their source areas. The remedial units are defined as follows:

- *A-Aquifer Groundwater Remedial Unit:* The length of the CT plume in the A-Aquifer is approximately 1.6 miles, and ranges from 500 to 750 feet in width along the length of the plume. The vertical extent of the affected groundwater in the A-Aquifer is assumed to correspond with its vertical thickness of 20 to 30 feet that rests above the thick, dense clay layer of the Fort Ord-Salinas Valley Aquitard (FO-SVA). The ACL for CT is 0.5 micrograms per liter (μg/L), and the maximum historic detected concentration in the A-Aquifer since groundwater monitoring was initiated in 1992 was 19 μg/L. The most recent maximum concentration of CT detected in the A-Aquifer in September 2004 was 15 μg/L. Groundwater in this aquifer flows northwest or west, and the top of the aquifer varies from 20 to 120 feet below ground surface (bgs). Because of the presence of the FO-SVA, there is no flow of groundwater between the A-Aquifer and the underlying aquifers in the OUCTP area except where the FO-SVA was penetrated by wells drilled into the lower aquifers without adequate sanitary seals. Two such 'vertical conduits' have been identified and have resulted in the migration of CT from the A-Aquifer to the underlying Upper and Lower 180-Foot Aquifers.

- *Upper 180-Foot Aquifer Groundwater Remedial Unit:* There are two narrow, parallel plumes in this aquifer. The western CT plume in the Upper 180-Foot Aquifer is approximately 0.7 miles in length and 400 feet in width. The eastern CT plume in the Upper 180-Foot Aquifer is approximately 0.9 miles in length and ranges from 200 to 600 feet in width. These plumes are migrating toward the southeast from two apparent vertical conduits through the overlying FO-SVA clay. The ACL for CT is 0.5 µg/L, and the maximum historic detected concentration in the Upper 180-Foot Aquifer since groundwater monitoring was initiated was 9.8 µg/L. The most recent maximum concentration of CT detected in the Upper 180-Foot Aquifer in September 2004 was 3.5 µg/L. The western plume contains low concentrations of CT (typically below 1 µg/L) with slightly higher concentrations (2 to 3 µg/L) observed at MW-BW-26-180. The eastern plume contains slightly higher concentrations of CT than the western plume and range from the detection limit to over 5 µg/L. The western plume appears to emanate from a vertical conduit at or near the Mini-Storage well (built in 1996), although the sanitary seal appears to have been adequate to prevent cross-communication between aquifers. The eastern plume emanates from monitoring well MW-B-13-A (built in 1975), where the sanitary seal was either inadequate or somehow failed resulting in hydraulic communication between the A- and Upper 180-Foot Aquifers. The vertical extent of the affected groundwater in the Upper 180-Foot Aquifer is assumed to correspond with its vertical thickness of about 60 feet, and is underlain by the Intermediate 180-Foot Aquitard, which is approximately 50 feet thick. Groundwater flows eastward and southeastward without flowing into other aquifers except within the southern portion of the OUCTP study area. The direction of flow appears controlled by the degree of hydraulic communication with the underlying Lower 180-Foot Aquifer, separated by the Intermediate 180-Foot Aquitard, where present. Where this aquitard pinches out, groundwater from the Upper 180-Foot Aquifer drains into the Lower 180-Foot Aquifer. The Upper 180-Foot Aquifer plume emanating from MW-B-13-180 migrated southeast toward the natural pinch-out of the underlying Intermediate 180-Foot Aquifer where is also entered the Lower 180-Foot Aquifer. The CT plume commingles with the Operable Unit 2 (OU2) trichloroethene (TCE) plume at this location.

- *Lower 180-Foot Aquifer Groundwater Remedial Unit:* There are two separate plumes in this aquifer. The northern CT plume in the Lower 180-Foot Aquifer is approximately 0.75 miles in length and 1,000 feet in width. The southern CT plume in the Upper 180-Foot Aquifer is defined by detections of CT at two monitoring wells approximately 0.5 miles apart that do not appear to form a continuous plume because CT has not been detected at monitoring wells in between these two wells. The ACL for CT is 0.5 µg/L, and the maximum historic detected concentration in the Lower 180-Foot Aquifer since groundwater monitoring was initiated was 6.95 µg/L. The most recent maximum concentration of CT detected in the Upper 180-Foot Aquifer in September 2004 was 3.6 μg/L. Continued downward CT migration through the same vertical conduits as have been identified in the FO-SVA and Upper 180-Foot Aquitard caused these two plumes to develop within the Lower 180-Foot Aquifer. Active migration may be occurring at or near the Mini-Storage well where CT continues to migrate east/northeast toward the Salinas Valley, comprising the northern CT plume in the Lower 180-Foot Aquifer. The vertical extent of the affected groundwater in the Lower 180-Foot Aquifer is assumed to correspond with its vertical thickness of approximately 200 feet and has historically been and continues to be a significant source of potable water for the former Fort Ord and City of Marina area. Vertical flow through the FO-SVA and Intermediate 180-Foot Aquitard is limited to locations at vertical conduits. Should these vertical conduits persist, groundwater may further migrate into the Lower 180-Foot Aquifer. The Upper 180-Foot Aquifer plume emanating from MW-B-13-180, however, migrated southeast toward the natural pinch-out of the underlying Intermediate 180-Foot Aquifer where it also entered the Lower 180-Foot Aquifer. The CT plume commingles with the OU2 TCE plume at this location and both contaminants appear to be migrating eastward toward the Marina Coast Water District (MCWD) municipal wells. To date, CT has not been detected in any of these drinking water wells; however, TCE has been detected at MCWD Well No. 29 at concentration ranging from 0.51 to 0.81 μg/L.

### *Remedial Technology Screening*

CERCLA guidance for RI/FSs requires that, prior to development of site-specific remedial alternatives, there is an initial screening of the universe of remedial technologies that could be used to cleanup contaminated sites (*EPA, 1989b*). Initially, specific technologies or process options are evaluated primarily on the basis of whether or not they can meet the RAOs. Potentially applicable remedial technologies were then identified based on previous bench-scale and pilot treatability studies conducted during the RI; experience in treating groundwater at the former Fort Ord; professional judgment; EPA and other remediation technology databases; and input from regulatory agencies. A range of technologies applicable to VOC contamination in groundwater for the OUCTP aquifers were identified and evaluated based on the initial criteria of effectiveness, implementability and relative cost as follows:

- *Effectiveness*—This criterion evaluates each technology based on its: proven ability to achieve cleanup goals, potential impacts on human health and the environment, and reliability with respect to site contaminants. Innovative technologies that have not been proven in full-scale operations but offer potentially substantial advantages in other areas (e.g., simplified operations) have been considered for alternative development.

- *Implementability*—This criterion evaluates the technical and administrative feasibility of implementing the technology at the site.

- *Relative Cost*—This criterion evaluates whether the capital and operating costs of implementing the technology are low, moderate or high as compared to other applicable technologies.

On the basis of this evaluation, technologies are screened, and those that are best suited to achieving the RAOs are retained for further consideration and are then combined to form remedial action alternatives for OUCTP. After review of site-specific conditions at OUCTP, several general response actions were identified for the technology screening and development of remedial action alternatives for groundwater to meet the RAOs. The general response actions that are potentially applicable are:

- No Action with Monitored Natural Attenuation—Taking no action to remediate contaminated groundwater, with continued groundwater monitoring for COCs and Monitored Natural Attenuation parameters.

- Containment—Containing contaminated groundwater using barriers.

- Collection—Extraction of contaminated groundwater for aboveground (ex situ) treatment.

- Treatment—In situ (belowground) and ex situ (aboveground) treatment of contaminated groundwater.

- Disposal—Reinjection or recirculation of treated water back into the aquifer, or discharge to the surface or drainage systems.

Three different categories of remedial technologies were retained for consideration that incorporate these general response actions: (1) no action with monitored natural attenuation; (2) in situ remediation, and (3) groundwater extraction and treatment. Various monitoring, containment, collection, treatment, and disposal options are identified and screened within each of the categories as applicable based on the evaluation criteria. The retained technologies are then evaluated in terms of the technical feasibility of remediating groundwater below aquifer cleanup levels if implemented. The following technologies were evaluated based on their effectiveness, implementability, and relative cost:

- No Action with Monitored Natural Attenuation;

- In Situ Remediation;

- Permeable Reactive Barrier (zero valent iron; adsorbent media);
- Enhanced Biodegradation (gaseous nutrient injection; Hydrogen Release Compound [HRC®]; emulsion-based amendments [edible oils, surfactants, etc.]; molasses; sodium lactate [used in a site-specific Biotreatability Pilot Study]);
- Groundwater Extraction and Treatment;
- Groundwater Extraction Technologies (vertical and horizontal extraction wells; drains or trenches);
- Groundwater Treatment Technologies (air stripping; activated carbon adsorption); and
- Groundwater Circulation and Disposal Technologies (reinjection, recirculation, sparging/in-well stripping wells; infiltration galleries; surface water or storm drain discharge).

### *Summary of Remedial Technology Screening*

Based on the screening of technologies, the following technologies and process options were retained for the development of remedial alternatives:

### *A-Aquifer Groundwater Remedial Unit*

- No Action with Monitored Natural Attenuation;
- In Situ Enhanced Biodegradation (e.g., injecting a carbon source such as lactate);
- In Situ Permeable Reactive Barrier; and
- Groundwater Extraction and Treatment (e.g., aboveground treatment using activated carbon adsorption or air stripping technologies).

### *Upper 180-Foot Aquifer Groundwater Remedial Unit*

- No Action with Monitored Natural Attenuation; and
- Groundwater Extraction and Treatment (as part of the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS).

### *Lower 180-Foot Aquifer Groundwater Remedial Unit*

- No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (e.g., using activated carbon adsorption or air stripping technologies).

### *Summary of Remedial Alternatives*

For the purposes of this FS, remedial alternatives were assembled to provide a logical and comprehensive approach for remediation of all three aquifers based on engineering judgment and the results of the remedial technology screening. The following assumptions associated with development of the alternatives will be further refined and reevaluated in the remedial design phase, during which many of the uncertainties and generalities present in this FS will be resolved, including the technical and economic feasibility of implementing the range of options considered herein:

- Alternate Remedial Technology Combinations and Cleanup Approaches (All Aquifers)—A number of alternate combinations of remedial technologies could be developed for remediation of each aquifer (e.g., extraction and treatment of groundwater from the downgradient portion of the plume and injection of nano-scale iron in discrete upgradient locations); various contingencies could be triggered for any of the point of compliance monitoring wells within any of the aquifers that contain COCs above ACLs; and non-attainment zones could be established for portions of the plumes that would be technically or economically infeasible to remediate below ACLs using a phased approach over time depending on the plume status. However, for the purposes of this evaluation, the most effective remedial technologies were assembled into stand-alone full-scale remedial alternatives for each plume and were evaluated in terms of their ability to achieve ACLs throughout the entire plume.

- Monitored Natural Attenuation (All Aquifers)—Wellhead treatment could be included as a contingency and be triggered for any of the point of compliance monitoring wells within any of the aquifers that contain COCs above ACLs. However, for the purposes of this evaluation, this contingency is only included in the evaluation of alternatives for the Lower 180-Foot Aquifer that is a current potable source of drinking water.

- In Situ Enhanced Biodegradation (A-Aquifer)—Injection of a number of different carbon sources could potentially be effective in enhancing the anaerobic biodegradation of CT in situ (e.g., HRC®, molasses, lactate). However, for the purposes of this evaluation, it is assumed the carbon source would be lactate because it was demonstrated to be effective in a site-specific pilot biotreatability study (Section 3.2.2).

- In Situ Permeable Reactive Barrier (A-Aquifer)—Injection of a number of different iron materials could potentially be implemented to enhance the degradation of CT in situ (e.g., zero-valent iron, nano-scale iron, nickel-plates iron, iron filings), in more than one location within the plume. However, for the purposes of this evaluation, it is assumed the iron material would be zero valent iron (ZVI) because it has proven effectiveness at the largest number of similar sites, and it would be implemented within a single downgradient (migration control) location. However, if it is determined the permeable reactive barrier (PRB) is not achieving adequate control and remediation of the plume, nano-scale iron could be injected at discrete locations throughout the plume (in lieu of installing additional barriers).

- Groundwater Extraction and Treatment (A-Aquifer)—Extraction wells (EWs) could be located based on a number of different configurations and considerations, such as in onsite primary source areas; the toe or leading edge of the plume; offsite downgradient locations where the plume has migrated; point-of compliance locations. However, for the purposes of this evaluation, it is assumed the EWs would be installed within the area of highest CT concentrations that are onsite and accessible in order to maximize source removal. In addition, aboveground treatment of extracted groundwater could potentially be achieved using a number of different technologies (e.g., activated carbon adsorption, air stripping, aeration, bioslurry) and configurations (e.g., modular wellhead treatment at individual wells, a single large-scale central processing treatment system). However, for the purposes of this evaluation, it is assumed either activated carbon or air stripping would be implemented at a central treatment system location because these technologies have proven effectiveness at many similar sites, and the equipment and infrastructure required to construct a single treatment system location are more readily available and typically less costly than individual wellhead treatment configurations.

The remedial alternatives are as follows:

- Remedial Alternative 1—No Action With Monitored Natural Attenuation (All Aquifers).

- Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Within OU2 groundwater treatment system (GWTS) (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

- Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

- Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

The alternatives are briefly summarized as follows:

Remedial Alternative 1—No Action With Monitored Natural Attenuation (All Aquifers). The no action alternative is required as a baseline for comparison to other alternatives (*EPA, 1989b*), and assumes:

- The plume(s) would naturally attenuate over a period of approximately 30 years to meet RAOs, and chemical concentrations in groundwater and offsite plume migration would not increase in a statistically significant manner.

- The two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated.

- Up to 30 additional "point of compliance" monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer, and would be monitored for a period of 30 years.

- A contingency plan would be developed for well-head treatment of groundwater being extracted from potable water supply wells if COCs associated with OUCTP are detected in these wells.

- Existing and newly installed groundwater wells within these aquifers would be monitored under the protocols of the existing monitoring program described in the RI (Volume I) using a phased approach over a 30-year period.

- Capital costs associated with planning and installing up to 30 additional monitoring wells to 'bound' the plumes are estimated at approximately $558,000. Operations and maintenance costs for 30 years of monitoring and reporting are estimated at approximately $2.19 million, for a total estimated 30-year net present value (NPV) cost of $2.75 million. Costs associated with contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would be estimated during the remedial design phase for implementation of the selected alternative.

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

This alternative presents (1) an in situ remediation scenario for treatment and migration control of the A-Aquifer groundwater plume using a large network of enhanced biodegradation injection points throughout the entire plume (Plate 5); (2) groundwater extraction and treatment and migration control of the Upper 180-Foot Aquifer using extraction wells (Plate 8) and treatment within the existing OU2 GWTS; and (3) monitored natural attenuation with wellhead treatment contingency of the Lower 180-Foot Aquifer if COCs are detected in water supply wells (Plate 4B).

As shown on Plate 5, which illustrates the in situ enhanced biodegradation carbon source injection locations and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 15 years of treatment (Year 15), this alternative would be effective at reducing COCs below ACLs, and would be implemented as follows.

***A-Aquifer***

- A line of 10 treatment cells that span the width of the plume would consist of a series of lactate injection points located every 40 feet across the cell installed to a depth of approximately 100 feet bgs.

- Approximately 250 gallons of a 60% sodium lactate solution would be injected at each injection point every 2.5 years until concentrations of COCs are at or below ACLs or are asymptotic (no longer declining) near ACLs (approximately 15 years, or a total of 6 injection events).

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated.

- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater being extracted from potable water supply wells if COCs associated with OUCTP are detected in these wells.

- Treatment system monitoring would be conducted as described under Alternative 1 for VOCs and natural attenuation parameters throughout the duration of treatment (15 years) and an additional 5 years of follow-up monitoring to assess the potential for concentrations of COCs to ‘rebound’ after treatment is discontinued, for a total duration of 20 years. Groundwater Monitoring of the OUCTP monitoring wells (MWs) would be conducted for a period of 30 years.

- Natural attenuation indicator data described under Alternative 1 would be analyzed to gauge the level of enhanced biodegradation within the aquifer and determine the need for and estimate the time between lactate reinjection events.

- Capital costs associated with installing the lactate injection and recirculation treatment system and additional monitoring wells, and conducting the first lactate injection event are estimated at approximately $4.63 million. Treatment system operations and maintenance costs for 15 years and 20 years of monitoring and reporting are estimated at approximately $4.90 million, for a total estimated 20-year NPV cost of $9.54 million.

### *Upper 180-Foot Aquifer*

This alternative presents a containment approach that includes a pumping scenario for migration control of the groundwater plume with aboveground treatment and reinjection of treated water back into the aquifer. This alternative assumes the newly installed groundwater extraction well EW-OU2-07-180 that is a component of the optimized Operable Unit 2 Groundwater Treatment System (OU2 GWTS) would be pumped at a total flow rate of approximately 150 gallons per minute (gpm) for capture of the majority of the Upper 180-Foot Aquifer plume as shown on Plate 8. The extracted water would be collected and treated at the existing aboveground central process and control area of the OU2 GWTS.

As shown on Plate 8, which illustrates the well locations, particle tracking streamlines, and concentrations of COCs within the plume from the most recent groundwater monitoring data (September 2004) that were used in the simulation, the results of the groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the majority of the Upper 180-Foot Aquifer plume to below ACLs within a time period of approximately 30 years as follows:

- The newly installed groundwater extraction well EW-OU2-07-180 that is a component of the optimized OU2 GWTS would be pumped at a total flow rate of approximately 150 gpm. Groundwater modeling indicated this well would also provide capture of the commingled CT plume associated with OU2 located near the area where these two plumes merge in the Upper 180-Foot Aquifer prior to entering the Lower 180-Foot Aquifer (Plates 3 and 8).

- Optimization procedures would need to be implemented within the OU2 GWTS to incorporate the additional flow of 150 gpm into the current treatment system, which has an approximate capacity limitation of 1,000 gpm.

- The extracted groundwater would require treatment within the existing OU2 GWTS to meet reinjection standards (discharge limits) for COCs, which are anticipated to be MCLs or detection limits using EPA Test Method 8260.

- A pipeline between the EW and the OU2 GWETS would need to be constructed to allow transfer of the extracted groundwater to the treatment plant. Treated effluent would be reinjected back into the aquifer through the reinjection wells associated with the existing OU2 GWTS.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot Aquifer will be eliminated, and groundwater monitoring of existing and new wells would be conducted as described under Alternative 1 for VOCs for a period of 30 years to assess the potential for concentrations of COCs to ‘rebound’ due to declining effectiveness of the groundwater extraction and treatment (GWET) system and to monitor the nature and extent of the plumes.

- Implementation of this alternative if it is selected would be conducted as part of optimization of the existing OU2 GWET system during the remedial design phase. Costs associated with installing additional extraction wells, piping conveyance to tie these wells into the existing OU2 GWETS, and additional treatment capacity to treat groundwater extracted from this aquifer would be estimated during the remedial design associated with the optimization of the OU2 GWTS.

### *Lower 180-Foot Aquifer*

- The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

<u>Remedial Alternative 3</u>—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

This alternative presents (1) an in situ remediation and containment approach that includes installation of an in situ PRB near the downgradient plume boundary for offsite migration control of the A-Aquifer plume (Plate 6); (2) groundwater extraction and treatment and migration control of the Upper 180-Foot Aquifer using extraction wells (Plate 8) and treatment within the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS); and (3) monitored natural attenuation with wellhead treatment contingency of the Lower 180-Foot Aquifer if COCs are detected in water supply wells.

The groundwater extraction and treatment alternative for the Upper 180-Foot Aquifer is the same for Remedial Alternatives 2-4, and is described in detail under Remedial Alternative 2. The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

### *A-Aquifer*

The in situ PRB would be installed near the downgradient plume boundary for offsite migration control of the A-Aquifer plume as shown on Plate 6, which illustrates the PRB location and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 30 years of treatment (Year 30), which is the cut-off for remedial alternative evaluations, cost estimating, and comparisons under EPA's RI/FS Guidance (*EPA, 1989b*). However, the results of the groundwater modeling simulation of this alternative indicated it would only be effective in remediating concentrations of COCs in the A-Aquifer plume to below aquifer cleanup levels (ACLs) within a time period of approximately 50 years in the area downgradient of the PRB, and typical PRB effectiveness timeframes are on the order of 20 years. Therefore, although the PRB may only be effective for a period of 20 years, and was not predicted to be able to achieve ACLs for up to 50 years, for the purposes of this evaluation, it was assumed to operate for a period of 30 years as specified under EPA's RI/FS Guidance (*EPA, 1989b*). Nano-scale iron could also be injected in a slurry form in isolated locations for targeted source removal in other portions of the plume to supplement the PRB, and would be further evaluated during the remedial design phase if this alternative is selected for implementation as follows:

- A pilot study would be conducted within a portion of the A-Aquifer plume to determine the site-specific effectiveness of this technology and (1) further refine design parameters such as iron consumption rates and effective flow-through thickness and residence times; (2) select a preferred injection technique; and (3) evaluate hydrogeologic data to analyze potential impacts of groundwater chemistry on the long-term performance of the PRB.

- If the results of the pilot study indicate a PRB would be effective, a full-scale PRB would be installed between monitoring wells MW-BW-43-A and MW-BW-44-A, east (upgradient) of the higher hydraulic conductivity zone coincident with the wave-cut terrace in the underlying FO-SVA (Plates 2A/2B and 6). This location was chosen for three reasons: (1) property within the former Fort Ord footprint is accessible for significant remedial activities associated with a PRB, (2) a roadway along the perimeter of the biological reserve provides an area where a PRB may be installed without disturbing the reserve, and (3) the depth to the FO-SVA is shallowest in this area (ranging from 35 to 65 feet), reducing the cost of installing a PRB relative to areas east or west of this location.

- The PRB would comprise three cells, fully penetrating the A-Aquifer, with a total length across the width of the plume (perpendicular to groundwater flow) of approximately 1,143 feet and a flow-through thickness of approximately 1 foot.

- The PRB cells would be constructed by installing ZVI or similar materials capable of long-lasting degradation of COCs. Laboratory bench-scale studies would be required to determine site-specific contaminant degradation rates and required residence times in ZVI or similar materials, and to evaluate the impact of groundwater chemistry on the long-term performance of the PRB.

- Although long term performance data is not available for PRBs, the typical effective remediation lifespan of a PRB is estimated at approximately 20-30 years. Groundwater modeling simulation results indicate that a PRB would take up to 50 years or more to passively remediate the A-Aquifer plume. Therefore, the PRB may have to be reinstalled should its ability to remediate the A-Aquifer decline over time. However, for the purposes of evaluating and costing this alternative, it is assumed to remediate the plume within a period of 30 years, which is the maximum period used for costing alternatives under EPA's RI/FS Guidance (*EPA, 1989b*).

- The PRB cells would be installed throughout the vertical depth of the A-Aquifer and be keyed into the silty clay aquitard (FO-SVA) that separated it from the Upper 180-Foot Aquifer to prevent the potential for underflow of contaminated groundwater beneath the PRB.

- Groundwater modeling indicated the PRB would remediate the majority of the CT plume upgradient of the PRB within 50 years, with only a small portion (located between the PRB and

MW-BW-31-A) of the plume remaining at concentrations ranging from 0.5 to 1.5 ug/L. However, groundwater downgradient of the PRB would remain contaminated at concentrations ranging between 0.5 and 5 ug/L due either to the continued migration of CT already present downgradient of the PRB or from residual CT emanating from the PRB. Therefore, it is anticipated that designation of a Non-Containment Zone may be required for this area since it would contain COCs above ACLs for an undetermined period of time.

- A disadvantage to installing a PRB in this area is that CT has been detected at concentrations exceeding the state MCL (0.50 ug/L) in monitoring wells downgradient of this area. In particular, the detection of 4.8 ug/L of CT at MW-BW-49-A in December 2004 indicates that a relatively significant amount of mass has already migrated into the high conductivity area of the A-Aquifer. The installation of a PRB further west (downgradient) of this monitoring well is not practicable due to dense residential and commercial development. Therefore, the PRB would allow a portion of the CT plume to continue migrating westward where it would be naturally attenuated over time, primarily by advective and dispersive processes.

- Up to 10 observation wells would be installed along the upgradient (5 wells) and downgradient (5 wells) lengths of the PRB to monitor concentrations of COCs and groundwater chemistry and assess the effectiveness of the barrier in remediating the plume.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated.

- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater being extracted from potable water supply wells if COCs associated with OUCTP are detected in these wells.

- Groundwater monitoring would be conducted as described under Alternative 1 for VOCs and natural attenuation parameters throughout the duration of treatment (15 years) and an additional 5 years of follow-up monitoring to assess the potential for concentrations of COCs to ‘rebound’ after treatment is discontinued, for a total duration of 20 years.

- Natural attenuation indicator data described under Alternative 1 would be analyzed to gauge the level of enhanced biodegradation within the aquifer and determine the need for reinjection of ZVI.

- Capital costs associated with installing the PRB and additional monitoring wells are estimated at approximately $8.73 million. Operations and maintenance and monitoring and reporting costs for 30 years are estimated at approximately $4.42 million, for a total estimated 30-year NPV cost of $13.15 million.

<u>Remedial Alternative 4</u>—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

This alternative presents a containment approach that includes a pumping scenario for migration control of the groundwater plume with aboveground treatment and reinjection of treated water back into the aquifer. The components of this alternative for the A-Aquifer are described below.

The groundwater extraction and treatment alternative for the Upper 180-Foot Aquifer is the same for Remedial Alternatives 2—4, and is described in detail under Remedial Alternative 2. The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

***A-Aquifer***

For the A-Aquifer, this alternative assumes five groundwater extraction wells pumping at a total flow rate of approximately 150 gpm for capture of the majority of the A-Aquifer plume within 30 years as shown on Plate 7. The extracted water would be collected at an aboveground central process and control area.

As shown on Plate 7, which illustrates the well locations, particle tracking streamlines, and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 30 years of treatment (Year 30). The results of the groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the majority of the A-Aquifer plume to below ACLs within a time period of approximately 30 years as follows:

- Five extraction wells would be installed within the A-Aquifer CT plume footprint to provide capture of the majority of the plume that lies upgradient of proposed extraction well (EW) EW-OUCTP-01.

- The extraction wells would pump at 50 gpm, 40 gpm, 30 gpm, 35 gpm, and 10 gpm from EW-OUCTP-01-A, EW-OUCTP-02-A, EW-OUCTP-03A, EW-OUCTP-04A, and EW-OUCTP-05-A, respectively.

- The portion of the plume that lies downgradient of EW-OUCTP-01 would not be technically feasible to capture, because based on the groundwater modeling simulation, any increase in the estimated pumping rate above 50 gpm would dry up the well. Concentrations of CT in the downgradient (uncaptured) portion of the plume are estimated to range from between 0.5 to 5 ug/L based on current plume conditions (the aquifer cleanup level for CT is 0.5 ug/L).

- Although concentrations of COCs in the downgradient portion of the plume are expected to decline over time (through advective and dispersive natural attenuation processes and reduction of the source of contamination as the upgradient plume is captured, treated, and reinjected), it is anticipated that designation of a “non-containment zone” may be required for this area since it would contain COCs above ACLs for an undetermined period of time.

- The extracted groundwater would require treatment to meet reinjection standards (discharge limits) for the COCs, which are anticipated to be MCLs or detection limits using EPA Test Method 8260.

- Given the low anticipated influent concentrations and the anticipated discharge requirements, treatment of extracted groundwater to below MCLs could be achieved by processing the water through activated carbon adsorption vessels or a low-flow air stripper. Both of these treatment options are included in the analysis of this alternative for comparison purposes, and because they are proven and effective methods for treating the extracted groundwater; have similar capital and operations and maintenance costs; and would be readily available for installation at a central processing and treatment location. A preferred treatment method would be identified in the remedial design phase if this alternative is selected for implementation.

- Based on preliminary vendor quotes (1) the activated carbon adsorption treatment system would consist of two 2,000-pound carbon vessels attached in series that would require changeout (replacement of spent carbon) and offsite regeneration approximately once a month, and (2) the air stripper treatment system would consist of a single stacked unit constructed of four air stripping trays that could be cleaned and maintained onsite. For both options, influent and effluent treatment system sampling for VOCs (EPA Test Method 8260) would be performed as part of routine operations and maintenance.

- A piping conveyance system would be installed between the five EWs and the GWETS to allow transfer of the extracted groundwater to a centrally located treatment plant north of Reservation Road (Plate 7). Piping connecting two of the EWs located south of Reservation Road to the treatment plant would need to be installed using horizontal drilling techniques beneath the road.

- Treated effluent would be reinjected back into the aquifer through reinjection wells located within the footprint of the plume to augment flow to the extraction wells, placed approximately along the plume axis.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated.

- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater (e.g., using activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP are detected in these wells.

- Groundwater monitoring of existing and new wells would be conducted as described under Alternative 1 for VOCs for a period of 30 years to assess the potential for concentrations of COCs to ‘rebound’ due to declining effectiveness of the GWET system and to monitor the nature and extent of the plumes.

- Capital costs associated with installing the extraction, treatment, and reinjection system and additional monitoring wells are estimated to range from approximately \$2.38 to \$2.45 million, depending on whether activated carbon or air stripping treatment is selected for implementation during the remedial design phase. Treatment system operations and maintenance costs for 30 years of monitoring and reporting range from approximately \$11.06 to \$17.46 million depending on the treatment method, for a total 30-year NPV estimated cost ranging from \$13.44 to \$19.92 million.

### *Evaluation and Comparison of Remedial Alternatives*

The alternatives are then evaluated and compared based on their ability to meet EPA's nine CERCLA evaluation criteria:

*Threshold Criteria*

- Overall Protection of Human Health and the Environment; and
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs).

*Balancing Criteria*

- Short-Term Effectiveness;
- Long-Term Effectiveness and Permanence;
- Reduction of Toxicity, Mobility, or Volume Through Treatment;
- Implementability; and
- Cost.

*Modifying Criteria*

- State (Regulatory) Acceptance; and
- Community Acceptance.

### *Preliminarily Identified Preferred Remedial Alternative*

The alternative that best met the nine EPA evaluation criteria and was preliminarily identified as the preferred remedial alternative for OUCTP is Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

This alternative was selected because it would likely be the most acceptable to the agencies and public because (1) it is the only alternative that would remediate the entire A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs within the shortest timeframe for the lowest associated cost, while (2) protecting human health and the environment and complying with ARARs, and (3) also providing long term monitored natural attenuation (MNA) and contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

Following issuance of a final OUCTP RI/FS report and Proposed Plan for public comment, a Record of Decision (ROD) will document the selected alternative(s). Responses to comments received during the public comment period will be found in a Responsiveness Summary which is part of the ROD. Once the ROD is issued, remedial design (if necessary) will begin. During the remedial design phase, many of the uncertainties and generalities present in the FS will be resolved.

# 1.0 INTRODUCTION

This volume of the Operable Unit Carbon Tetrachloride Plume Remedial Investigation/Feasibility Study (OUCTP RI/FS) report presents the Feasibility Study that identifies potential remedial options and selects preferred remedial alternatives to address groundwater contaminants present in three distinct aquifers within the OUCTP at the former Fort Ord in Monterey County, California (Plate 1). The results of this Feasibility Study will be used to support the OUCTP RI/FS Proposed Plan and Record of Decision (ROD) that will document the results of the Remedial Investigation (RI; Volume I), Human Health Risk Assessment (HHRA; Volume II) and this Feasibility Study (FS; Volume III).

MACTEC has prepared this FS report for the United States Army Corps of Engineers (USACE) under Contract No. GS-10F-0157K, Order number DACA05-02-F-0006, in accordance with the scope of work dated March 8, 2002.

## 1.1 Purpose and Objectives

As outlined in Superfund under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and National Contingency Plan (NCP; 40 CFR 300), the objective of the feasibility study is to develop and evaluate a range of potentially applicable remedial alternatives so an appropriate remedial action can be selected. This FS for OUCTP is based on the U.S. Environmental Protection Agency's (EPA's) Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (*EPA, 1989b*) (EPA's RI/FS Guidance). EPA's RI/FS process represents the methodology that Superfund has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options (*EPA, 1989a*). The goal of the RI/FS process is to "gather information sufficient to support an informed risk management decision regarding which remedy appears most appropriate for a given site" (*EPA, 1989a*). To achieve this goal, the OUCTP RI characterized the contamination present at the site (Volume I), and the HHRA assessed human health risks associated with potential exposure to chemicals of concern in groundwater and provided recommendations for aquifer cleanup levels that would be protective of human health (Volume II).

The objectives of this FS are to (1) review the findings and recommendations presented in the RI and HHRA and summarize the results, (2) define the Remedial Action Objectives (RAOs) for cleanup of VOCs detected in these aquifers, and (3) describe the process used to develop, evaluate, compare and select preferred alternatives that will meet the RAOs based on the results of the RI and HHRA.

The purpose of this FS is to develop and evaluate a range of alternatives that could be implemented to remediate volatile organic compound (VOC) contamination, specifically carbon tetrachloride (CT), detected in groundwater of the A-Aquifer, Upper 180-Foot Aquifer, and Lower 180-Foot Aquifers within OUCTP (Plates 2-4).

The development and selection of remedial alternatives require the following steps presented in this FS:

- Defining remedial action objectives (RAOs) by identifying federal and State chemical-, location-, and action-specific Applicable or Relevant and Appropriate Requirements (ARARs) and specifying the contaminants and media of interest, exposure pathways, and remediation goals, so that a range of treatment and containment alternatives can be developed;

- Identifying specific remedial units (volumes or areas of media that share similar characteristics and contaminants) for which general response actions may be applied;

- Identifying potential treatment and containment technologies from the general response actions that will satisfy the RAOs for each remedial unit identified;

- Screening the technologies based on their effectiveness, implementability, and cost;

- Assembling technologies and their associated containment or treatment combinations into remedial alternatives for each remedial unit identified;

- Conducting a detailed analysis of the range of remedial alternatives developed—that vary primarily in their cost to implement, operate, and maintain, and the time required to meet the RAOs—by evaluating and comparing them based on EPA's nine CERCLA evaluation criteria to address the statutory requirements and preferences of EPA guidance (*EPA, 1988*) and the National Contingency Plan (NCP); and

- Selecting a preferred remedial alternative for each remedial unit that best meets the evaluation criteria.

Each remedial action must: (1) be protective of human health and the environment, (2) attain ARARs, (3) be cost-effective, and (4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

Remedial actions in which treatment permanently and significantly reduces the volume, toxicity or mobility of the contaminants are to be preferred over those not involving such treatment. If the selected remedial action does not reflect this preference, then the Record of Decision shall explain why it does not. The detailed analysis of alternatives consists of the analysis and presentation of sufficient information to allow decision makers to select a remedy by comparing the alternatives against each other, and is required to meet specific statutory requirements for remedial actions that are addressed in a Record of Decision (ROD) and are supported by the FS report.

Following issuance of a final OUCTP RI/FS and Proposed Plan for public comment, a ROD will document the selected alternatives. Responses to comments received during the public comment period will be found in a Responsiveness Summary which is part of the ROD. Once the ROD is issued, remedial design (if necessary) will begin. During the remedial design phase, many of the uncertainties and generalities present in the FS will be resolved.

## 1.2 Report Organization

This FS report is organized as follows:

Section 1.0: Introduction—Describes the purpose and objectives of this FS, the report organization, and summarizes the results of the Remedial Investigation (RI) and Human Health Risk Assessment (HHRA) conducted for OUCTP.

Section 2.0: Remedial Action Objectives—Defines the Remedial Action Objectives (RAO), cleanup levels, and remedial units for which remedial alternatives will be developed to address contaminants in groundwater based on the results of RI and HHRA and an initial assessment of potential Applicable or Relevant and Appropriate Requirements (ARARs).

Section 3.0: Remedial Technology Screening—Identifies the range of applicable response actions and remedial technologies capable of achieving the RAOs, and screens them for applicability to groundwater contamination found within the remedial units that will be considered in the development of remedial alternatives. Technologies are preliminarily evaluated on the basis of three of the evaluation criteria: effectiveness, implementability, and relative cost.

Section 4.0: Development of and Description of Remedial Alternatives—Presents the development of comprehensive remedial alternatives and describes the conceptual components of each alternative.

Section 5.0: Detailed Analysis of Remedial Alternatives—Presents the evaluation and comparison of potential remedial alternatives based on the EPA's CERCLA evaluation criteria.

Section 6.0: Preliminarily Identified Preferred Remedial Alternative—Presents the rationale for preliminarily identifying a preferred remedial alternative and summarizes the preferred alternative.

Section 7.0: Approval Process—Describes the approval process for documenting the selection and implementation of a preferred alternative in the RI/FS Proposed Plan and ROD.

Section 8.0: References—Provides a list of references to pertinent documents cited in this report.

Appendix A: Remedial Alternative Cost Estimates—Presents preliminary cost estimates and assumptions involved in the implementation of each remedial alternative evaluated.

## 1.3 Summary of OUCTP Characteristics and Potential Risks

This section briefly summarizes the results of the RI and HHRA for OUCTP, which are presented in Volumes I and II of this report, respectively.

### 1.3.1 Summary of OUCTP Characteristics

The RI report (Volume I) documented the lithologic, chemical, and hydrogeologic data that has been collected to determine the lateral and vertical extent of contamination, specifically CT, detected in groundwater of the A-Aquifer, Upper 180-Foot Aquifer, and Lower 180-Foot Aquifers. No contamination has been observed in the 400-Foot Aquifer wells and no CT has been detected in the Lower 180-Foot Aquifer active drinking water wells serving the Fort Ord community.

CT was not detected during any soil sampling activities conducted as part of the RI, and residual CT in soil vapor was removed during a soil vapor extraction (SVE) pilot study at the site near the suspected source area. Based on the OUCTP RI data, it appears there is no longer a source of VOC contamination to groundwater in OUCTP as follows:

- At the time the SVE pilot study was conducted in 2004, soil gas concentrations indicated there was not a sufficient mass of VOCs present to represent a current source of underlying groundwater contamination.
- Concentrations of VOCs suspended in soil vapor appear to represent a low-level residual mass from previous infiltration of contamination following the disposal of solvents approximately 50 years ago.
- VOC concentrations in groundwater underlying the contaminated portion of the vadose zone have consistently been detected at very low concentrations (in the parts per billion [ppb] range),

indicating there is no longer an ongoing contribution of VOCs into groundwater from a surface or soil vapor source.

- Over the last 50 years, it appears that non-contaminated groundwater upgradient of the area has continued to migrate beneath the site, effectively flushing residual VOCs from the A-Aquifer.

A source of CT contamination is no longer in contact with groundwater. Therefore, contamination throughout the OUCTP is in the aqueous phase, and the plumes are no longer attached to their source areas.

The following sections summarize the nature and extent of CT contamination in groundwater within each of the three aquifers.

### *A-Aquifer*

CT has been historically detected in this aquifer at concentrations up to 19 μg/L (micrograms per liter, or ppb) (Plates 2A/2B). The most recent groundwater monitoring data collected in September 2004 indicates a current maximum concentration of CT in this aquifer of 15 μg/L. The Federal MCL for CT in groundwater is 5.0 μg/L, and the State MCL for CT in groundwater is 0.5 μg/L. Chloroform is the primary breakdown or ‘daughter’ product of CT and its presence throughout the CT plume indicates that some degree of natural attenuation (i.e., dechlorination and breakdown of CT) is occurring in the subsurface environment. Based on the estimated time of release to the A-Aquifer (circa 1950), the apparent source location (what is now Lexington Court), and the current downgradient extent of the CT plume (approximately 9,500 feet), CT has migrated through the A-Aquifer at a rate of approximately 0.5 feet per day. As of September 2004, CT has been detected a distance of 1.6 miles northwest of the source area and the CT plume in this aquifer ranges from 500 to 750 feet in width (Plates 2A/2B).

The A-Aquifer is the uppermost aquifer with a vertical thickness of 20 to 30 feet that rests above a thick, dense clay layer known as the FO-SVA. Groundwater in this aquifer flows northwest or west, and the top of the aquifer varies from 20 to 120 feet bgs. Because of the presence of the FO-SVA, there is no flow of groundwater between the A-Aquifer and the underlying aquifers in the OUCTP area except where the FO-SVA was penetrated by wells drilled into the lower aquifers without adequate sanitary seals. Two such ‘vertical conduits’ have been identified and have resulted in the migration of CT from the A-Aquifer to the underlying Upper and Lower 180-Foot Aquifers.

Although the plume is typically migrating at only 0.5 feet per day throughout the majority of the aquifer due to subsurface phenomena such as sorption of VOCs onto soil particles, groundwater in this aquifer typically travels at a rate of about 20 feet per day from the source area to midway along the A-Aquifer CT plume. It then passes over a subsurface “wave-cut terrace” instead of the smoother, more gently sloping contour typical of the FO-SVA, where it increases in flow in isolated locations to as high as 560 feet per day near the downgradient ‘toe’ of the plume. This phenomenon of groundwater moving much faster in portions of the ‘toe’ of the plume, which corresponds geographically with the northwestern boundary of the former Fort Ord, has resulted in CT in the A-Aquifer migrating ‘offsite’ into groundwater beneath the City of Marina (Plate 2B).

### *Upper 180-Foot Aquifer*

CT has been historically detected in this aquifer at concentrations up to 9.8 μg/L (Plate 3). The most recent groundwater monitoring data collected in September 2004 indicates a current maximum concentration of CT in this aquifer of 3.5 μg/L. The State Maximum Contaminant Level (MCL) for CT in groundwater is 0.5 μg/L.

CT and its daughter product chloroform have been observed in two narrow, parallel plumes in this aquifer that are migrating toward the southeast from two apparent vertical conduits through the overlying FO-SVA clay (Plate 3). The western plume contains low concentrations of CT (typically below 1 μg/L) with slightly higher concentrations (2 to 3 μg/L) observed at MW-BW-26-180 (screened near the bottom of the Upper 180-Foot Aquifer). The eastern plume contains slightly higher concentrations of CT than the western plume and range from the detection limit to over 5 μg/L. The western plume appears to emanate from a vertical conduit at or near the Mini-Storage well (built in 1996), although the sanitary seal appears to have been adequate to prevent cross-communication between aquifers. The eastern plume emanates from monitoring well MW-B-13-A (built in 1975), where the sanitary seal was either inadequate or somehow failed resulting in hydraulic communication between the A- and Upper 180-Foot Aquifers.

The Upper 180-Foot Aquifer has a vertical thickness of about 60 feet and extends throughout the OUCTP study area, and is underlain by the Intermediate 180-Foot Aquitard, which is approximately 50 feet thick. Groundwater flows eastward and southeastward under largely confined conditions (without flowing into other aquifers) except within the southern portion of the OUCTP study area with hydraulic conductivity ranging from 100 to over 1,000 feet/day. The direction of flow appears controlled by the degree of hydraulic communication with the underlying Lower 180-Foot Aquifer, separated by the Intermediate 180-Foot Aquitard, where present. Where this aquitard pinches out, groundwater from the Upper 180-Foot Aquifer drains into the Lower 180-Foot Aquifer.

### *Lower 180-Foot Aquifer*

CT has been historically detected in this aquifer at concentrations up to 6.95 µg/L (Plates 4A/4B). The most recent groundwater monitoring data collected in September 2004 indicates a current maximum concentration of CT in this aquifer of 3.6 µg/L. The State MCL for CT in groundwater is 0.5 µg/L.

Continued downward CT migration through the same vertical conduits as have been identified in the FO-SVA and Upper 180-Foot Aquitard caused two plumes to also develop within the Lower 180-Foot Aquifer. Active migration may be occurring at or near the Mini-Storage well where CT continues to migrate east/northeast toward the Salinas Valley, comprising the northern CT plume in the Lower 180-Foot Aquifer. This plume appears to terminate beneath the Marina Airport (previously known as the Fritzsche Army Airfield [FAAF]). The Upper 180-Foot Aquifer plume emanating from MW-B-13-180, however, migrated southeast toward the natural pinch-out of the underlying Intermediate 180-Foot Aquifer where it also entered the Lower 180-Foot Aquifer. The CT plume commingles with the OU2 TCE plume at this location and both contaminants appear to be migrating eastward toward the MCWD municipal wells. To date, CT has not been detected in any of these drinking water wells; however, TCE has been detected at MCWD Well No. 29 at concentration ranging from 0.51 to 0.81 µg/L, with the higher concentrations consistently being detected during late summer months.

The Lower 180-Foot Aquifer has a vertical thickness of approximately 200 feet and has historically been and continues to be a significant source of potable water for the former Fort Ord and City of Marina area. Given an approximate aquifer thickness of 140 feet, the approximate hydraulic conductivity of the Lower 180-Foot Aquifer is 330 feet/day. Significant pumping from this aquifer since the 1940's, both locally and regionally, has resulted in seawater intrusion that extends within the northern portion of the OUCTP study area. Horizontal hydraulic conductivity values have been difficult to determine, given waste discharge limitations, but have been successfully simulated at 700 feet/day. This aquifer is the local equivalent of the regional 180-Foot Aquifer and passive groundwater elevation monitoring clearly illustrates seasonal and daily pumping cycles from irrigation wells located in the Salinas Valley, east of the OUCTP study area.

Pumping from the Salinas Valley has reversed the direction of flow within the Upper 180-Foot and Lower 180-Foot Aquifer. Beneath the site, groundwater in the Upper 180-Foot Aquifer flows to the southeast toward the apparent edge of the underlying Intermediate 180-Foot Aquitard where it then recharges the Lower 180-Foot Aquifer. Groundwater primarily migrates to the east in the Lower 180-Foot Aquifer but oscillates between a northeast direction in the summer (in response to increased pumping from the Salinas

Valley) and a more southeast direction (locally in response to the MCWD Well Nos. 29, 30, and 31).

Vertical flow through the FO-SVA and Intermediate 180-Foot Aquitard is limited to locations at vertical conduits. Should these vertical conduits persist, groundwater may further migrate into the Lower 180-Foot Aquifer.

### 1.3.2 Summary of Potential Risks

Potential human health risks from exposure to VOCs detected in groundwater and soil gas from OUCTP were evaluated in the Human Health Risk Assessment (HHRA; Volume II). The HHRA addressed the excess risks to the residents posed by the chemicals of potential concerns (COPCs) present in the groundwater and soil gas. The HHRA was conducted in accordance with U.S. Environmental Protection Agency (EPA), California Environmental Protection Agency (Cal/EPA)-Department of Toxic Substances Control (DTSC), and U.S. Army Corps of Engineers (USACE) guidance.

The results of the HHRA (Volume II) for OUCTP indicate that there is a potential cancer risk for a future onsite resident that uses untreated groundwater from OUCTP for drinking and household water purposes and vapor intrusion to indoor air. It should be noted that groundwater from OUCTP is not currently supplied for domestic use, and the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999. Therefore, the estimated risks are based on a hypothetical “worst-case” scenario under which an individual installs a private drinking water well without authority, permit, or approval, and uses it exclusively for their drinking and household water purposes.

A hypothetical on-site resident represents the most conservative exposure scenario evaluated. Contamination in the A-Aquifer was associated with the highest estimated cancer risk (1E-05); followed by the Upper 180 Foot-Aquifer (E-06); and then the Lower 180-Foot Aquifer (2E-06). Noncancer hazards were less than 1.

The HHRA evaluation was accomplished by reviewing the groundwater and soil gas data collected at the site, identifying COPCs in groundwater and soil gas, selecting appropriate exposure assumptions and toxicity criteria, and estimating human health risks and hazards. A detailed evaluation of the available groundwater and soil gas data was conducted to identify data applicable to the HHRA. The following criteria were used to select appropriate and representative data for inclusion in the HHRA (Section 2.1 of Volume II):

- **Sample location** – Groundwater samples collected from all monitoring wells within the OUCTP network were included in the HHRA data set, with the exception of Westbay monitoring wells MP-BW-41 and MP-BW-42. Samples from these two wells were not included in the HHRA data set because groundwater from these wells is being captured and treated by the existing OU2 GWTS.

- **Sample date -** The most recent groundwater data are considered most representative of current and future concentrations. Therefore, the HHRA focused on groundwater monitoring data from the most recent sampling events from August 2003 to September 2004.

Soil gas data has been collected from July 2002 to October 2004. A soil vapor extraction (SVE) pilot study was conducted in two phases. Phase I started April 6, 2004 and was shut down on June 14, 2004. Phase II started September 9, 2004 and was shut down on November 8, 2004 (Section 3.10 of Volume I). Data that were collected post-Phase I SVE pilot study are considered most representative of current and future conditions.

- **Sample depth -** The groundwater data were divided into four data sets, A-Aquifer, upper 180 foot, lower 180-400 foot, and 400 foot, and evaluated separately in the HHRA. Samples that were collected at different depths from a single well within an aquifer were evaluated as a single sample by averaging the results.

  Soil gas samples were collected at depths ranging from 6 to 85 feet bgs. In the HHRA, data collected at 6 feet bgs was utilized as it is considered most representative of contaminant concentrations in the shallow vadose zone.

- **Duplicate samples -** Duplicate samples were also collected for selected soil gas samples. For duplicate samples, the following criteria were used to select the results to be applied in the HHRA: 1) where all results were reported as non-detect, the most conservative (i.e., highest) reporting limit was used in the HHRA; 2) where all results were reported as detected, the highest of the results was used in the HHRA; and 3) where there were both detected and non-detected results, the highest detected result was used in the HHRA.

- **Analyte -** The OUCT plume is monitored for VOCs by EPA test methods 524.2, 8260, and/or 8260B for groundwater and by EPA test method TO-15 for soil gas.

- **Data validation and assigned qualifiers -** Data that were used in the HHRA included acceptable validated data without qualifiers or with the following qualifiers: J (estimated value; U (non-detect); UJ (estimated non-detect reporting limit). Data with an R (rejected) qualifier were not included in the HHRA.

The groundwater data sets went through a screening process to select COPCs (Section 2.2 of Volume II). COPCs are the chemicals in groundwater and soil gas that, based on concentration and toxicity, are most likely to contribute significantly to risks calculated for the exposure pathways evaluated in the HHRA. All chemicals that were detected in soil gas were included in the HHRA evaluation, but a screening process was used to select the COPCs in groundwater. For each groundwater data set (or aquifer), a chemical was selected as a COPC if the frequency of detection (FOD) was greater than 2.5 % in the HHRA data set. This criterion was used for COPC selection so that chemicals that have either been routinely detected in each aquifer and/or recently detected within the last year would be evaluated in the HHRA. Additionally, chemicals were qualitatively evaluated to remove chemicals from the evaluation due to suspect results from sampling equipment and techniques (i.e., acetone, methyl ethyl ketone [MEK], and vinyl chloride [VC]) and to include chemicals (i.e., bromoform) that were not frequently detected but have a weight-of-evidence classification as a probable human carcinogen.

The OUCTP primarily underlies a residential community that receives potable water from the Marina Coast Water District (MCWD). Groundwater within the OUCTP is located in a “prohibition zone,” which is an area overlying or adjacent to a contaminant plume where water well construction is prohibited and applications for water supply wells will not be accepted. However, it was conservatively assumed in the HHRA that current and future residents would be exposed to groundwater within the OUCTP during domestic use and vapor intrusion to indoor air. The following potentially complete exposure pathways are identified and quantitatively evaluated for child and adult residents in the HHRA:

- Ingestion of groundwater – Exposure of residents to groundwater contaminants assuming that they may ingest contaminated groundwater as drinking water;

- Dermal contact with groundwater during domestic use – Exposure of residents to groundwater contaminants may result from dermal contact while to showering and/or bathing;

- Inhalation of vapors from groundwater in indoor air – Exposure of residents to contaminants may result from volatilization during showering and domestic water use; and

- Inhalation of vapors migrating from soil gas to indoor air – Exposure of residents to contaminants may result from the migration of volatile contaminants from the subsurface into indoor air.

Toxicity assessment is the process of using the existing toxicity information from human and/or animal studies to identify potential health risks at various dose levels in exposure populations (*EPA, 1989a*). To estimate these potential health risks, the relationship between exposure to a chemical (in terms of chronic DI for individuals) and an adverse effect (in terms of bodily response to a specific intake dose level) must be quantified. The methodologies used to develop toxicity factors differ, depending on whether the COPC is a potential carcinogen (i.e., has the potential to cause cancer) and/or has noncancer adverse effects. As part of the toxicity assessment cancer and noncancer toxicity values were compiled for each COPC for use in the risk characterization process.

The risk characterization integrates the COPC selection, exposure assessment, and toxicity assessment to describe the risks to individuals in terms of the nature and likelihood of potential adverse health risks to occur. The risk characterization process involved integrating the exposure intakes and toxicity values to estimate both cancer risk and noncancer hazards to potential residential receptors from exposure to COPCs in groundwater at the site. The risks and hazards were calculated for two exposure scenarios. For the reasonable maximum exposure (RME) scenario, it was assumed that an onsite resident would be exposed to VOCs in groundwater 350 days per year for a total duration of 30 years. These are very conservative assumptions considering that residents do not typically reside at one place for a total of 30 years. For the average exposure (AE) scenario, it was assumed that adult and child residents would be exposed for a total duration of 9 and 6 years, respectively.

Table 21 in Volume II summarizes the total estimated cancer risks by aquifer for all exposure pathways evaluated in the HHRA. Adult and child resident RME risks estimated for each aquifer range from 2E-06 to 1E-05. For AE conditions, the estimated risks are 4E-07 and 2E-06 for the adult and child resident, respectively. The A-Aquifer was associated with the highest estimated risk, followed by the Upper 180 Foot-Aquifer, and the Lower 180-400 Foot-Aquifer.

Ingestion of groundwater contributed approximately 76 to 81 % of the total risk. Dermal contact contributed approximately 17 to 23 %, and intrusion of vapors into indoor air contributed approximately 0.4 to 2 % of the total estimated risks. Risks associated with inhalation of vapors while showering was negligible.

The total estimated cancer risks by COPC and pathway for each aquifer are presented in Volume II Tables 13 through 20. Risk drivers (i.e., those COPCs contributing to 10 % or greater of the total risk) associated with direct ingestion of groundwater by aquifer are as follows:

- A-Aquifer: CT (63 %) and tetrachloroethene (PCE) (22 %).

- Upper 180 Foot-Aquifer: CT (96 %).
- Lower 180-400 Foot-Aquifer: 1,2-dichloroethane (1,2-DCA) (21 %) and CT (73 %), though the ingestion risk from 1,2-DCA was below 1E-06.

Risk drivers associated with dermal contact are:

- A-Aquifer: CT (54 %) and PCE (42 %).
- Upper 180 Foot-Aquifer: CT (98 %), though the total dermal risk was below 1E-06.
- Lower 180-400 Foot-Aquifer: CT (92 %), though the total dermal risk was below 1E-06.

Table 21 of Volume II summarizes the total estimated noncancer hazards by aquifer for all exposure pathways evaluated in the HHRA. The total RME hazards estimated for the aquifers ranged from 0.03 to 0.2 for the adult resident and 0.07 to 0.5 for the child resident. Under AE conditions, the hazards for the aquifers are 0.02 to 0.2 for the adult resident and 0.05 to 0.4 for the child resident.

# 2.0 REMEDIAL ACTION OBJECTIVES

This section defines the RAO for OUCTP groundwater impacted by volatile organic compounds (VOCs); presents an assessment of potential ARARs and summarizes the results of the Human Health Risk Assessment (HHRA; Volume II) used to develop aquifer cleanup levels; and defines the remedial units (plumes or the extent of the aquifers impacted by VOCs) for which remedial alternatives will be developed based on the results of Remedial Investigation (RI; Volume I) as follows:

Section 2.1—Definition of Remedial Action Objectives.

Section 2.2—Applicable or Relevant and Appropriate Requirements.

Section 2.3—Identification of Aquifer Cleanup Levels.

Section 2.4—Definition of Groundwater Remedial Units.

## 2.1 Definition of Remedial Action Objectives

The primary RAOs for OUCTP groundwater impacted by VOCs are (1) to reduce risks to human health and the environment, and (2) comply with ARARs such as federal, State, and local laws.

RAOs are established to allow the identification and screening of remedial alternatives that will achieve protection of human health and the environment consistent with reasonably anticipated land use. No ecological receptors were identified as potentially being exposed to VOCs in groundwater within OUCTP; therefore, risks to the environment were not assessed.

Cleanup levels are acceptable contaminant levels that when achieved within a site, would mitigate potential risks and comply with ARARs. Section 2.3 defines ACLs for OUCTP that were developed based on (1) a preliminary assessment of the ARARs discussed in Section 2.2 and summarized in Table 1; and (2) the results of the HHRA summarized in Volume II of this report. If ARARs are not available for a particular chemical or situation or if ARARs are not sufficient to protect human health and the environment, critical toxicity factors such as EPA-established reference doses or cancer potency factors identified in the HHRA may be used to estimate risk-based remediation goals consistent with EPA guidance, to ensure that a remedial action is protective of human health and the environment (*EPA, 1993*). Final ARARs, compliance with ARARs, and the applicability of any waivers of ARARs will be determined when the remedial action is selected, as described in the Proposed Plan and finalized in the Record of Decision.

The following RAOs are proposed for groundwater within OUCTP:

- Exposure Control—Prevent the potential exposure of child and adult residents to groundwater contaminants above ACLs; and

- To the extent practicable based on technical and economic feasibility, achieve:

  --Source Control—Prevent or minimize further degradation of groundwater at the site;

  --Plume Containment—Mitigate the potential for contaminants to continue to migrate offsite; and

  --Plume Remediation—Reduce contaminant concentrations in groundwater to below ACLs.

The following section presents an analysis of ARARs that will be considered in the development of ACLs in Section 2.3 and the subsequent screening of remedial technologies and evaluation of remedial alternatives.

## 2.2 Potential Applicable or Relevant and Appropriate Requirements (ARARs)

Under CERCLA, remedial actions must be protective of human health and the environment and comply with federal or more stringent State ARARs, unless waived. Promulgated requirements are "laws imposed by state legislative bodies and regulations developed by state agencies that are of general applicability and are legally enforceable." Formally promulgated and consistently applied State or federal policies have the same weight as specific standards. Advisories and policy or guidance documents (to-be-considered requirements, or TBCs) issued by federal or state agencies that are not legally binding are not considered to be ARARs but may be included as performance standards if selected in the ROD.

ARARs are identified for each remedial action proposed in an FS. ARARs are chemical-, location-, and action-specific requirements, as discussed below. Chemical-specific ARARs are identified and used to develop ACLs. However, when ARARs are not available, more stringent cleanup goals are established such that residual health risks after remediation fall within acceptable ranges.

Remedial actions implemented at a Superfund site must control further release of hazardous substances, pollutants, and contaminants to assure the protection of human health and the environment. Any hazardous substance, pollutant, or contaminant left onsite must be managed or controlled, upon completion of remedial actions, to meet ARARs.

The documents *CERCLA Compliance with Other Laws Manual* and *Guidance for Development of Applicable or Relevant and Appropriate Requirements Under CERCLA* (*EPA, 1993*) contain detailed information on identifying and complying with ARARs. This guidance issued by the EPA defines ARARs as follows:

- Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or State law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to a particular site. The relevance and appropriateness of a requirement are judged by comparing the factors addressed to the characteristics of the remedial action, the hazardous substance(s) in question, and the physical characteristics of the site. The origin and objective of the requirements may aid in determining its relevance and appropriateness. Although relevant and appropriate requirements must be complied with to the same degree as applicable requirements, more discretion is allowed in determining which part of a requirement is relevant and appropriate.

- TBCs, the final class of requirements considered by EPA during the development of ARARs, are nonpromulgated advisories or guidance documents issued by federal or state governments. They do not have the status of ARARs but may be considered in determining the necessary cleanup levels or actions to protect human health and the environment.

The following three categories of ARARs are defined by EPA (*EPA, 1989b*):

- Ambient or chemical-specific requirements that set health- or risk-based concentration limits or ranges for particular chemicals (e.g., National Ambient Air Quality Standards).

- Location-specific requirements pertaining to restrictions placed on concentrations of hazardous substances or remedial activities (e.g., federal and State laws governing the siting of hazardous waste facilities).

- Performance-design-, or action-specific requirements that govern particular activities with respect to remedial actions taken for hazardous wastes (e.g., hazardous wastes generated onsite must be properly managed according to federal and State laws).

If ARARs are not available for a particular chemical or situation or if ARARs are not sufficient to protect human health and the environment, critical toxicity factors such as EPA-established reference doses or cancer potency factors identified in the HHRA may be used to estimate risk-based remediation goals consistent with EPA guidance, to ensure that a remedial action is protective of human health and the environment (*EPA, 1991b*). Section 2.3 defines aquifer cleanup levels (ACLs) for OUCTP that were developed based on ARARs and the risk-based assessment provided in the HHRA (Volume II).

To identify the possible ARARs and for remedial actions that may be considered for OUCTP at the former Fort Ord; federal, State, and local statutes, regulations, and guidance were considered. In the following sections, potential ARARs are identified for groundwater at OUCTP; a summary of all potential ARARs are provided in Table 1. This FS report considers all ARARs in performing the detailed analysis and comparisons of the remedial alternatives in Section 5.0. The chemical-specific, location-specific, and action-specific requirements are discussed below.

### 2.2.1 Chemical-Specific Requirements

The following chemical-specific requirements have been identified for consideration.

Water Quality Control Plan, Central Coast Regional Water Quality Control Board (RWQCB): The Basin Plan establishes criteria for groundwater to be considered a drinking water source. The Plan (Resolution No. 89-04, dated November 17, 1989; amended February 1994 and as appropriate on a regular basis) also contains requirements for implementation plans or action plans for attaining compliance with these standards. The requirements of the Basin Plan are applicable to groundwater remediation activities. Each Regional Board promulgates and administers a Water Quality Control Plan for ground and surface water basin(s) within its region. The State Board also promulgates statewide water quality control plans that the regional boards administer. The Plans establish water quality standards (including beneficial use designations, water quality objectives to protect these uses, and implementation programs to meet the objectives) that apply statewide or to specific water basins.

Portions of the Central Coast Region Basin Water Quality Control Plan are ARARs. The Basin Plan classifies groundwater based on beneficial uses. This classification is based on "data collected by the local agencies and/or dischargers regarding the quality and use of waters in their vicinity." Groundwater at OUCTP is considered a potential drinking water, industrial water, and agricultural water source under the Basin Plan; applicable California State Water Resources Control Board Resolutions are described under Action-Specific Requirements. Through these resolutions, the consideration of maximum benefit is limited to the range between Maximum Contaminant Levels (MCLs) and ‘non-detectable’ for most groundwater basins in the State. The groundwater cleanup standards for the Site are based on applicable water quality objectives and are the more stringent of federal and State MCLs. Cleanup to these levels will result in acceptable residual risk to humans. The goal of the remedial actions evaluated herein is to restore the beneficial uses of groundwater underlying and adjacent to the Site. Results from other sites suggest that full restoration of beneficial uses of groundwater as a result of active remediation at this Site may not be possible. If full restoration of beneficial uses is not technologically nor economically achievable within a reasonable period of time, then the Army may request modification to the cleanup standards or establishment of a containment zone, a limited groundwater pollution zone where water quality objectives are exceeded. Conversely, if new technical information indicates that cleanup standards can be surpassed, the Board may decide if further cleanup actions should be taken. A discussion of the technical and economic feasibility of remediating groundwater below aquifer cleanup levels is provided in Section 3.4 specific to each remedial technology retained for consideration as a remedial alternative within OUCTP.

<u>National Primary Drinking Water Standards:</u> These regulations, promulgated under the Safe Drinking Water Act and found in 40 Code of Federal Regulations (CFR) Part 141, establish MCLs permissible for a public water system. MCLs are the highest levels of contaminants allowed in drinking water, and are enforceable standards. Maximum Contaminant Level Goals (MCLGs) have also been promulgated under 1986 Amendments to the Safe Drinking Water Act. MCLGs are (1) levels of contaminants in drinking water below which there is no known or expected risk to health, (2) allow for a margin of safety, and (3) are non-enforceable public health goals. MCLGs above zero are considered chemical-specific ARARs under the NCP (40 CFR 300.430[e][2][i][B]). When MCLGs are equal to zero (which is generally the case for any chemical considered to be a carcinogen), the MCL is considered to be a chemical-specific ARAR, instead of the MCLG (40 CFR 300.430[e][2][i][C]). MCLs area set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. These requirements are considered relevant and appropriate. Those federal MCLs that are more stringent than State MCLs are ARARs, and are used as Aquifer Cleanup Levels (Section 2.3; Table 2).

<u>State Primary Drinking Water Standards:</u> California Safe Drinking Water Act of 1976 (Health and Safety Code [H&SC] §§ 4010.1 and 4026(c). California has established standards for sources of public drinking water under this Act. California Code of Regulations (CCR) Title 22, Chapter 15, includes California's primary drinking water standards which establish enforceable limits for chemicals that may affect public

health or the aesthetic qualities of drinking water. Some State MCLs are more stringent than federal MCLs. In these instances, the more stringent State MCLs are applicable for OUCTP. There are also some chemicals that lack a federal MCLs. For these chemicals, where State MCLs exist, they are applicable for OUCTP. CCR Title 22, Section 64449 also contains California's secondary drinking water MCLs that pertain to minimum aesthetic qualities of drinking water. Those MCLs that are more stringent than federal standards are ARARs, and are used as ACLs (Section 2.3; Table 2).

Identification and Listing of Hazardous Waste: 22 CCR, Division 4.5, Chapter 11 establishes/defines procedures and criteria for identification and listing of Resource Conservation Recovery Act (RCRA) and non-RCRA hazardous wastes. Chemicals regulated as hazardous waste, and the levels at which they are hazardous, are identified in these regulations.

If groundwater from OUCTP is extracted for aboveground treatment and contaminants are collected in treatment media (e.g., in granular activated carbon vessels), depending on the concentrations of contaminants present, the media must be managed (e.g., carbon beds must be regenerated to remove the contaminants or disposed accordingly) as a characteristic waste under the federal hazardous waste program (RCRA), which is now regulated by the State of California. Listed and characteristic hazardous wastes are identified and defined in 22 CCR, Division 4.5, Chapter 11.

National Primary and Secondary Ambient Air Quality Standards (NAAQS): The federal Clean Air Act, Section 109, 42 USCA 7401-7642 defines National Primary and Secondary Ambient Air Quality Standards (NAAQS), which are listed in 40 CFR 150. Under certain circumstances, these may be applicable; however, for the region of California in which the former Fort Ord is located, the Monterey Bay Unified Air Pollution Control District (MBUAPCD) requirements are applicable instead because they incorporate NAAQSs and in some cases more stringent requirements specific to the Monterey Bay Area.

If groundwater from OUCTP is extracted for aboveground treatment and the contaminant treatment system is vented to the atmosphere (e.g., using an air stripper), depending on the concentrations of contaminants present, the offgas effluent must be managed (e.g., further treated using activated carbon adsorption polishing) to remove concentrations of any contaminants above these standards.

Monterey Bay Unified Air Pollution Control District (MBUAPCD): The MBUAPCD regulates new sources (Regulation II) and toxic air contaminants, (Regulation X, Rule 207), and restricts specific discharges of organic compounds to the atmosphere through remedial actions (e.g., removal of organic compounds from groundwater using air stripping) in accordance with Regulation X. The MBUAPCD requirements may limit emissions of total and individual organic compounds on a site-specific basis and/or may require emission controls.

Under Rule 207, emissions of most individual volatile organic compounds (VOCs) are generally restricted to 25 pounds per day using Best Available Control Technology (BACT), and total VOCs are restricted to 150 pounds per day. In addition, the MBUAPCD regulates releases of certain identified or potential air toxics at levels determined to be "appropriate for review." In some cases, a risk assessment may be required. The MBUAPCD requirements are potential ARARs for treatment of groundwater by methods generating emissions and remedial actions will be designed to ensure compliance with this ARAR. Groundwater treatment system emissions to the atmosphere are anticipated to be minimal; however, if groundwater extraction and aboveground treatment are selected for implementation, the remedial design will address the management and treatment of these emissions, if determined to be necessary, in compliance MBUAPCD requirements.

### 2.2.2 Location-Specific Requirements

Fort Ord is located on California’s central coast, a biologically diverse and unique region. The range and combination of climatic, topographic, and soil conditions at Fort Ord support many biological communities. Field surveys were conducted from 1991 through 1994 to provide detailed site-specific, as well as basewide, information regarding plant communities, botanical resources, observed and expected wildlife, and biological resources of concern. Plant communities were mapped for the whole base as described in the *Draft Basewide Biological Inventory, Fort Ord, California* (*HLA, 1992*).

A significant portion of the OUCTP area is typically described as including the following plant communities: central maritime chaparral; Coast live oak woodland; grassland; and developed/landscaped areas. Central maritime chaparral is the most extensive natural community at Fort Ord, occupying approximately 12,500 acres in the south-central portion of the base. Grasslands, located primarily in the southeastern and northern portions of the base, occupy approximately 4,500 acres. The remaining approximately 11,000 acres of the base are considered fully developed and not defined as ecological communities.

Special-status biological resources (including plant and wildlife taxa and native biological communities) occur at the former Fort Ord that receive various levels of protection under local, State, or federal laws, regulations, or policies. The closure and disposal of Fort Ord is considered a major federal action that could affect several species of concern and other rare species that are listed by the California Department of Fish and Game (CDFG) and/or the California Native Plant Society (CNPS), or are listed as threatened or endangered under the federal Endangered Species Act (ESA). The U.S. Department of the Interior, Fish and Wildlife Service's (USFWS's) final *Biological Opinion for the Disposal and Reuse of Fort Ord* (*USFWS, 1993*) required that a habitat management plan (HMP; *USACE, 1997*) be developed and implemented to reduce the incidental take of listed species and loss of habitat that supports these species. The HMP for Fort Ord complies with the USFWS Biological Opinion and establishes the guidelines for the conservation and management of wildlife and plant species and habitats that largely depend on Fort Ord land for survival (*HLA, 1997*). Of the 12 plant communities identified at Fort Ord, two are considered rare or declining and of highest inventory priority by the CDFG (*CDFG, 1997*): central maritime chaparral and valley needlegrass grassland. Special-status taxa that occur or potentially occur in the plant communities at Fort Ord include 22 vascular plants, 1 invertebrate, 4 reptiles, 1 amphibian, 9 birds, and 2 mammals.

Within the area of OUCTP, specific resources of concern include Monterey spineflower (*Chorizanthe p. pungens*), sand gilia (*Gilia tenuiflora arenaria*), sandmat manzanita (*Arctostaphylos pumila*), toro manzanita (*Arctostaphylos montereyensis*), coast wallflower (*Erysimum ammophilum*), Monterey ceanothus (*Ceanothus cuneatus rigidus*), Eastwood's goldenbush (*Ericameria fasciculata*), and the black legless lizard (*Anniella pulchra nigra*). Coast live oak (*Quercus agrifolia*) woodland is considered to be potential habitat for the Monterey ornate shrew (*Sorex ornatus salarius*) and the Monterey dusky-footed woodrat (*Neotoma fuscipes luciana*).

The following location-specific requirements have been identified for consideration.

<u>Endangered Species Act of 1973:</u> The Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) requires action to conserve endangered species and preserve or restore a critical habitat upon which they depend. OUCTP contains areas that have specific resources of concern; therefore, this act may be an ARAR. Potential locations for siting of OUCTP groundwater extraction and/or treatment systems will be screened for potential environmental impacts to any endangered species identified in the *Installation-Wide Multispecies Habitat Management Plan(HMP) for Former Fort Ord, California* (*USACE, 1997*). The HMP report recommends measures, as necessary, to ensure compliance with this ARAR for any remedial actions implemented at the former Fort Ord.

<u>California Endangered Species Act:</u> Fish and Game Code, Section 2050 et seq. provides for the recognition and protection of rare, threatened and endangered species of plant and animals (in conjunction with State authorized or funded actions). OUCTP contains areas that have specific resources of concern; therefore, this act may be an ARAR. Potential locations for siting of OUCTP groundwater extraction and/or treatment systems will be screened for potential environmental impacts to any endangered species

identified in the HMP (*USACE, 1997*), which recommends measures, as necessary, to ensure compliance with this ARAR for any remedial actions implemented at the former Fort Ord.

The Fish and Wildlife Coordination Act: This act, 16 U.S.C. 661 et seq., requires fish and wildlife to be protected if remedial actions modify the drainage channel or other features of the stream or river. No foreseeable remedial action at OUCTP would modify a drainage or other stream feature. Therefore, this act is not an ARAR.

Coastal Zone Management Act: This act (16 USC 1456 et seq.) requires activities conducted within the coastal zone to be conducted in a manner consistent with the State-approved management program. OUCTP does not lie within the coastal zone; therefore, this act is not an ARAR.

California Coastal Act of 1976: This act, Public Resources Code Section 3000 et seq., established the State Coastal Zone Management Plan. Activities within the coastal zone are to be conducted in a manner consistent with a coastal management plan. OUCTP does not lie within the coastal zone; therefore, this act is not an ARAR.

Migratory Bird Treaty Act: This act, 16 U.S.C. 703 et seq., protects certain migratory birds and their nests and eggs. Migratory birds may be present within the OUCTP area. Potential locations for siting of OUCTP groundwater extraction and/or treatment systems will be screened for potential environmental impacts to any endangered species identified in the HMP report, which recommends measures, as necessary, to ensure compliance with this ARAR for any remedial actions implemented at the former Fort Ord.

Waste Management Unit Classification and Siting - Fault Zone: Under 40 CFR 264.18a, new hazardous waste treatment, storage, or disposal (TSD) units are prohibited from being located within 200 feet of a geologic fault displaced in Holocene time. OUCTP is located within a seismically active region, but not near such a fault. Therefore, the prohibition stated above does not apply to the potential siting of groundwater extraction and/or treatment systems.

Waste Management Unit Classification and Siting - Floodplain: Requirements under 40 CFR 264.18b state that a hazardous waste TSD facility should not be located within a 100-year floodplain unless it is design to prevent washout of any waste by a 100-year flood. Potential locations for siting of OUCTP groundwater extraction and/or treatment systems are not located within a 100-year floodplain; therefore 40 CFR 264.18b does not apply.

Standards for the Management of Wastes Discharged to Land: This title establishes standards for the management of waste discharged to land. Title 23 CCR, Division 3, Chapter 15, Article 2 (Waste Classification and Management), Section 2511(d) provides exemptions to these requirements for cleanups taken at the direction of public agencies, as long as requirements of Article 2 are met for waste that is removed from the point of release under any remedial alternatives and disposed untreated. Contaminated groundwater from OUCTP would not discharged to land untreated, but would be properly treated and disposed in accordance with other ARARs depending on the discharge method selected (e.g., if groundwater is discharged to a Publicly Owned Treatment Work [POTW], it would be performed in accordance with applicable regulations such as the Federal Safe Drinking Water Act).

### 2.2.3 Action-Specific Requirements

The following action-specific requirements have been identified for consideration.

Porter - Cologne Water Quality Control Act, Chapter 1 (Section 13000, et seq), Division 7, of the California Water Code; California State Water Resources Control Board Resolutions:

- Resolution No. 88-63: "Sources of Drinking Water" (also known as the Sources of Drinking Water Policy) specifies that all ground and surface water is an existing or potential source of drinking water unless: (1) total dissolve solids (TDS) are greater than 3,000 parts per million (ppm or milligrams per liter [mg/L]), (2) the well yield is less than 200 gallons per day (gpd) from a single well, or (3) the groundwater is unreasonable to treat using best management practices or best economically achievable treatment practices. Groundwater in all three aquifers of concern in OUCTP (A-Aquifer; Upper 180-Foot Aquifer; Lower 180-Foot Aquifer) meet the first two criteria under Resolution 88-63 (i.e., TDS levels are below 3,000 ppm; well yield is above 200 gpd); whether it meets the third criteria (i.e., that it is reasonable to treat using best management practices or best economically achievable treatment practices) will be addressed based on the results of the groundwater modeling conducted in the RI (Volume I) under the development and evaluation of remedial alternatives in Sections 4.0 and 5.0.

  This resolution is applicable to OUCTP and can be used to establish a general criteria for designating water use. Groundwater in the aquifers within the former Fort Ord inclusive of the OUCTP area is not currently used for drinking water; however, these aquifers are potential drinking water sources and have been identified as having beneficial uses including domestic, agricultural, and industrial water supplies. It should be noted that due to the former Fort Ord's status as a federal Superfund site with several documented groundwater contaminant plumes

(Operable Units 1, 2, Sites 2/12, and OUCTP), the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999. Groundwater in the lower aquifers at the former Fort Ord inclusive of the OUCTP area (Lower-180-Foot and 400-Foot Aquifers) is extracted for use as drinking water by the adjacent City of Marina and is expected to continue to be used as a drinking water source.

- State Board Resolution Number 68-16: "Statement of Policy with Respect to Maintaining High Quality of Waters in California" (also known as the Non-Degradation Policy) applies to the discharge of COCs to groundwater within OUCTP and requires attainment of background levels of water quality, or the highest level of water quality which is reasonable if background levels of water quality cannot be restored. Cleanup levels other than background must be consistent with the maximum benefit to the people of the State, not unreasonably affect present and anticipated beneficial uses of such water, and not result in exceedance of applicable water quality objectives. This resolution establishes goals for the maintenance of existing groundwater quality and requires that waters that are of higher quality than the water quality objectives within a basin plan must be maintained at the higher quality. It also requires best practical control technology for discharges to high quality water, excluding reinjection of water into a contaminated groundwater plume. Resolution 68-16 is not a 'zero discharge' standard but rather a statement that existing quality be maintained when it is reasonable to do so. Specifically, where any activities result in discharges to high quality waters, dischargers shall use the best practicable treatment or control of the discharge necessary to avoid pollution or nuisance and to maintain water quality consistent with maximum benefit to the people of the State. Discharges to high quality waters (outside the contaminated plume) will be treated to "nondetected" as measured by applicable EPA Methods. Discharges to water overlying the groundwater plume are not considered discharges to high quality water, and would be treated using the best demonstrated available technology to achieve Aquifer Discharge Levels set for other groundwater remedies at the former Fort Ord that are the same as or lower than MCLs (Section 2.3; Table 2).

- Resolution Number 92-49: "Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304" (also known as the Containment Zone Policy) applies to the discharge of COCs to groundwater within OUCTP and establishes policies and procedures for the investigation, cleanup, and abatement of waste. Under this resolution, dischargers are required to cleanup and abate the effects of discharges in a manner that promotes attainment of either background water quality, or the best water quality which is reasonable if background levels of water quality cannot be restored, considering all the demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible. This resolution requires the application of Title 23 CCR, Division 3, Chapter 15, Section 2550.4 (Chapter 15) requirements to cleanups. In Chapter 15, cleanup levels must be set at background levels, or if background levels are not technologically or economically feasible, then at the lowest levels that are technologically or economically achievable. Remedial alternatives for groundwater at OUCTP will be developed to attain the highest water quality which is reasonable based on all demands to be considered above. Any groundwater treatment system that may be implemented will use the best control technology to treat groundwater prior to discharge. The goal of remedial action is to restore the beneficial uses of groundwater underlying and adjacent to the Site. Results from other sites suggest that full restoration of beneficial uses of groundwater as a result of active remediation at this Site may not be possible. If full restoration of beneficial uses is not technologically nor economically achievable within a reasonable period of time, then the Army may request modification to the cleanup standards or establishment of a containment zone, a limited groundwater pollution zone where water quality objectives are exceeded. Conversely, if new technical information indicates that cleanup standards can be surpassed, the Board may decide if further cleanup actions should be taken. A discussion of the technical and economic feasibility of remediating groundwater below aquifer cleanup levels is provided in Section 3.4 specific to each remedial technology retained for consideration as a remedial alternative within OUCTP.

Federal Safe Drinking Water Act – Underground Injection Control (UIQ: 40 CFR 144): This act prohibits injection of contaminated water into or above a drinking water formation. For OUCTP, treated groundwater may be injected to the aquifer to aid/accelerate the remediation process and/or dispose of extracted and treated groundwater. Injected groundwater would not contain chemical concentrations above MCLs or, in this case, Aquifer Discharge Levels (Section 2.3; Table 2).

Federal Safe Drinking Water Act – National Pollutant Discharge Elimination System (NPDES) (40 CFR 122): This act establishes permitting standards for discharge of pollutants from any point source into waters of the United States. Treated groundwater from OUCTP may be discharged to waters of the State of California. The substantive requirements of meeting effluent limitations and monitoring under an NPDES permit would be followed if such a discharge is implemented as a component of a selected remedial alternative.

Federal Safe Drinking Water Act – Publicly Owned Treatment Work (POTW) (40 CFR Part 403-5): This act allows municipalities to determine pretreatment standards for POTWs within its jurisdiction.

These standards are ARARs only if treated or untreated groundwater from OUCTP is discharged to a POTW. These standards would be followed if such a discharge is implemented as a component of a selected remedial alternative.

California Toxic Injection Well Act - CA H&S Code Section 25159.24[a]: This act prohibits injection of contaminated water into or above a drinking water formation. This Act exempts injection of treated groundwater for the purpose of improving groundwater quality. For OUCTP, treated groundwater may be injected to the aquifer to aid/accelerate the remediation process and/or dispose of extracted and treated groundwater. Injected groundwater would not contain chemical concentrations above MCLs or, in this case, Aquifer Discharge Levels (Section 2.3; Table 2).

Water Well Standards - California Department of Water Resources (Bulletin 74-81): These standards are a To-Be-Considered (TBC) requirement for construction or destruction of water wells in the State. For OUCTP, wells may be constructed and/or destroyed within the aquifer to aid/accelerate/monitor the remediation process and/or dispose of extracted and treated groundwater. Because these standards are not promulgated, they have been identified as a TBC and may be applicable for new well construction and/or destruction of wells.

National Primary and Secondary Ambient Air Quality Standards (NAAQS): The federal Clean Air Act, Section 109, 42 USCA 7401-7642 defines National Primary and Secondary Ambient Air Quality Standards (NAAQS), which are listed in 40 CFR 150. Under certain circumstances, these may be applicable; however, for the region of California in which the former Fort Ord is located, compliance with the substantive requirements of the Monterey Bay Unified Air Pollution Control District (MBUAPCD) are considered applicable instead because they incorporate NAAQSs and in some cases more stringent requirements specific to the Monterey Bay Area.

If groundwater from OUCTP is extracted for aboveground treatment and the contaminant treatment system is vented to the atmosphere (e.g., using an air stripper), depending on the concentrations of contaminants present, the offgas effluent must be managed (e.g., further treated using carbon adsorption polishing) to remove concentrations of any contaminants above these standards.

Monterey Bay Unified Air Pollution Control District (MBUAPCD): The MBUAPCD regulates new sources (Regulation II) and toxic air contaminants, (Regulation X, Rule 207), and restricts specific discharges of organic compounds to the atmosphere through remedial actions (e.g., removal of organic compounds from groundwater using an air stripper) in accordance with Regulation X. The MBUAPCD requirements may limit emissions of total and individual organic compounds on a site-specific basis and/or may require emission controls.

Under Rule 207, emissions of most individual volatile organic compounds (VOCs) are generally restricted to 25 pounds per day using Best Available Control Technology (BACT), and total VOCs are restricted to 150 pounds per day. In addition, the MBUAPCD regulates releases of certain identified or potential air toxics at levels determined to be "appropriate for review." In some cases, a risk assessment may be required. Compliance with the substantive requirements of the MBUAPCD will be considered for treatment of groundwater by methods generating emissions and remedial actions will be designed to ensure compliance with this ARAR. Groundwater treatment system emissions to the atmosphere are anticipated to be minimal; however, if groundwater extraction and aboveground treatment are selected for implementation, the remedial design will address the management and treatment of these emissions, if determined to be necessary, in compliance MBUAPCD requirements.

<u>Criteria for All Waste Management Units, Facilities, and Disposal Sites:</u> Title 27 California Code of Regulations, Division 3, Chapters 1-6; Subchapter 3. Water Monitoring, Article 1. SWRCB - Water Quality Monitoring and Response Programs for Solid Waste Management Units. A waste management unit (WMU) has not been established at OUCTP related to the source of contamination to groundwater. However, these regulations would be considered in establishing a “point of compliance” evaluation monitoring program for management of the residual groundwater contamination within OUCTP as part of the selected remedial actions for OUCTP where there has been a "measurably significant" evidence of a release from an unknown source where cleaning solvents are suspected to have been disposed (Section 4.0 of RI; Volume I). As specified in Section 4.0, the Army intends to implement a groundwater monitoring program as a component of all remedial alternatives for OUCTP. The monitoring program will establish “points of compliance”, (i.e., groundwater monitoring wells within the plume) (Section 2.4; Description of Groundwater Remedial Units) and ‘background wells’ outside of the plume boundary for management of the residual groundwater contamination within OUCTP as part of the selected remedial actions for OUCTP that will include relevant components of Title 27 CCR regulations (e.g., Section 20405: Monitoring Points and the Point of Compliance, et. Seq.) for monitoring chemicals of concern (COC) established in the Record of Decision.

<u>Standards for Owners and Operators of Hazardous Waste Treatment. Storage, and Disposal Facilities</u>: Hazardous waste has not been identified at OUCTP, but if it is identified, the following regulations would be applicable:

- Title 22 CCR, Chapter 14, Use and Management of Containers; Article 9, Sections 66264.171-178. Establishes requirements for the use of containers to store hazardous waste. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Section 66171; Condition of Containers. Containers for hazardous waste must be maintained in good condition. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Section 66172; Compatibility of Waste in Containers. Containers for hazardous waste must be compatible with the wastes stored in them. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Section 66173; Management of Containers. Containers holding hazardous waste must be closed during storage except when necessary to add or remove waste. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements. Hazardous materials storage will be isolated and able to maintain control of incidental spills or leaks.

- Title 22 CCR, Section 66174; Inspections. Containers and container storage areas must be inspected weekly for leaks or deterioration. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Section 66175; Containment. Container storage areas must be designed according to the requirements of this section. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite. Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Section 66178; Closure. At closure, all hazardous waste and waste residues must be removed and remaining containment structures decontaminated. Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite.  Appropriate actions will be taken to comply with such requirements.

- Title 22 CCR, Chapter 14, Article 2, Section 66264.14; Public Access Restrictions.  Owners and operators of hazardous waste treatment, storage, or disposal (TSD) facilities must prevent the unknowing entry of persons or livestock onto the active portions of the facility; in addition, warning signs must be posted.  Relevant and appropriate if hazardous waste is treated, stored, or disposed onsite; areas will be restricted from public access.
- Title 22 CCR, Chapter 14, Article 7, Section 66264.119; Post Closure Notices.  Under this requirement, a restriction is placed on the deed which contains future uses of the property. Remedial measures in which hazardous levels of chemical constituents remain in place may be subject to these regulations.  Appropriate actions will be taken to comply with such requirements.
- Title 22 CCR, Chapter 14, Article 16, Section 66264.601; Miscellaneous Units.  These regulations apply to facilities that treat, store, or dispose of hazardous waste in miscellaneous units.  Owners and operators of TSDs at which hazardous waste is stored in miscellaneous units must locate, design, construct, operate, maintain, and close those units in a manner that is protective of human health and the environment.  Applicable if drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous may be stored in containers onsite.  These containers may be considered miscellaneous treatment units while being stored, if hazardous; however, they will be disposed offsite according to these regulations.

<u>Standards Applicable to Generators of Hazardous Waste:</u>  Establishes standards for generators of hazardous waste under Title 22, CCR, Chapter 12.  Applicable if hazardous waste is generated at the sites; the substantive portions of these regulation will apply and be complied with.

<u>Land Disposal Restrictions:</u>  Title 22 CCR, Chapter 18 prohibits land disposal of specified untreated hazardous wastes and provides special requirements for handling such wastes.  It requires laboratory analysis of wastes intended for landfill disposal to establish that the waste is not restricted from landfill disposal.  Applicable if listed or characteristic hazardous wastes exists in the form of drill cuttings, decontamination water, or groundwater treatment residues subsequently characterized as hazardous are generated.  Any such wastes will be disposed offsite according to these regulations.

## 2.3 Proposed Aquifer Cleanup Levels

As described in Section 2.1, the primary Remedial Action Objectives (RAOs) for OUCTP groundwater impacted by volatile organic compounds (VOCs) are (1) to reduce risks to human health and the environment, and (2) comply with Applicable or Relevant and Appropriate Requirements (ARARs) such as federal, State, and local laws.

More specifically, the following RAOs are proposed for groundwater within OUCTP:

- Exposure Control—Prevent the potential exposure of child and adult residents to groundwater contaminants above ACLs; and
- To the extent practicable based on technical and economic feasibility, achieve:

  --Source Control—Prevent or minimize further degradation of groundwater at the site;

  --Plume Containment—Mitigate the potential for contaminants to continue to migrate offsite;

  --Plume Remediation—Reduce contaminant concentrations in groundwater to below aquifer cleanup levels (ACLs).

A general discussion of the technical feasibility of remediating groundwater below ACLs is provided in Section 3.4 specific to each remedial technology retained for consideration as a remedial alternative within OUCTP for the parameters described in Section 2.2.3 (Action-Specific ARARs) and summarized in Table 1. The economic feasibility of achieving ACLs is discussed in the detailed analysis of alternatives presented in Section 5.0.

Proposed ACLs for each of the three aquifers in OUCTP are presented in Table 2. These ACLs were developed as follows:

Chemicals of Concern (COCs)—COCs were identified based on their concentration, frequency of detection, and toxicity, and an assessment of their contribution to cumulative risks as described in Section 2.2 of the HHRA;

Federal and State drinking water levels (Maximum Contaminant Levels; MCLs) were reviewed for each COC (*National Primary Drinking Water Standards* [*EPA, 2003*] and State of California Department of Health Services' *MCLs, DLRs and PHGs for Regulated Drinking Water Contaminants* [*DHS, 2004*]).

The results of the HHRA (Volume II) for OUCTP indicate that there is a potential cancer risk for a future onsite resident that uses untreated groundwater from OUCTP for drinking and household water purposes. It should be noted that groundwater from OUCTP is not currently supplied for domestic use, and in general, “exposure control” is achieved for OUCTP because the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999. Therefore, the estimated risks are based on a hypothetical “worst-case” scenario under which an individual installs a private drinking water well without authority, permit, or approval, and uses it exclusively for their drinking and household water purposes.

A hypothetical on-site resident represents the most conservative exposure scenario evaluated. Contamination in the A-Aquifer was associated with the highest estimated cancer risk (1E-05); followed by the Upper 180 Foot-Aquifer (E-06); and then the Lower 180-Foot Aquifer (2E-06). Noncancer hazards were less than 1. These cumulative risk estimates for exposure to contaminants in groundwater are within the EPA and Cal/EPA-DTSC cancer risk management range of 1 in 10,000 to 1 in 1,000,000 (or alternately 1E-4 to 1E-6), but greater than the Cal/EPA-DTSC’s point of departure for risk management of 1 in 1,000,000. Noncancer hazards are less than 1 in each aquifer for all receptors. Therefore, the more conservative or lower of the federal or State MCLs for each COC within the OUCTP plume were selected as ACLs as summarized in Table 2 because total risks estimated in the HHRA (Volume II) are within regulatory risk management ranges, and MCLs are enforceable standards for chemicals that may affect public health or the aesthetic qualities of drinking water. A further discussion of MCLs as ACLs is provided in Section 2.2 under the description of ARARs.

## 2.4 Description of Groundwater Remedial Units

The three groundwater remedial units are defined as the groundwater plumes at OUCTP containing dissolved VOCs that exceed aquifer cleanup levels (MCLs; Table 2) based on the maximum chemical concentration detected for each COPC from groundwater monitoring data collected in September 2004 as shown on Plates 2-4, respectively.

### 2.4.1 A-Aquifer Groundwater Remedial Unit

The lateral extent of the affected groundwater in the uppermost A-Aquifer is illustrated on Plates 2A/2B based on the September 2004 data. The distribution of the COCs in this aquifer (CT, PCE, and TCE) above aquifer cleanup levels (MCLs; Table 2) is contained within these lateral limits. The CT plume (ranging in concentration from 0.25 to 15 μg/L) extends from Lexington Court to the north and then northwest and terminates in the vicinity of Seacrest Avenue in the City of Marina (Plate 2B). CT has been detected a distance of 1.6 miles northwest of the source area and the CT plume in this aquifer ranges from 500 to 750 feet in width. Seasonal variations in concentration or lateral extent are negligible in the A-Aquifer. The results of the RI indicated the source of CT contamination is no longer in contact with groundwater. Therefore, contamination throughout the OUCTP is in the aqueous phase, and the plumes are no longer attached to their source areas.

The vertical extent of the affected groundwater in the A-Aquifer is assumed to correspond with its vertical thickness of 20 to 30 feet that rests above the thick, dense clay layer of the FO-SVA. Groundwater in this aquifer flows northwest or west, and the top of the aquifer varies from 20 to 120 feet below ground surface (bgs). Because of the presence of the FO-SVA, there is no flow of groundwater between the A-Aquifer and the underlying aquifers in the OUCTP area except where the FO-SVA was penetrated by wells drilled into the lower aquifers without adequate sanitary seals. Two such ‘vertical conduits’ have been identified and have resulted in the migration of CT from the A-Aquifer to the underlying Upper and Lower 180-Foot Aquifers.

Although the plume is typically migrating at only 0.5 feet per day throughout the majority of the aquifer due to subsurface phenomena such as sorption onto soil particles, groundwater in this aquifer typically travels at a rate of about 20 feet per day from the source area to midway along the A-Aquifer CT plume. It then passes over a subsurface “wave-cut terrace” instead of the smoother, more gently sloping contour typical of the FO-SVA, where it increases in flow in isolated locations to as high as 560 feet per day near the downgradient ‘toe’ of the plume. This phenomenon of groundwater moving much faster in portions of the ‘toe’ of the plume, which corresponds geographically with the northwestern boundary of the former Fort Ord, has resulted in CT in the A-Aquifer migrating ‘offsite’ into groundwater beneath the City of Marina (Plate 2B).

Because CT has migrated the furthest distance in the A-Aquifer and is consistently detected at much higher concentrations above MCLs than the other COCs (PCE and TCE), OUCTP has been defined and is typically characterized as a CT plume. As summarized in Table 2, the ACL for CT is 0.5 μg/L, and the maximum historic detected concentration in the A-Aquifer since groundwater monitoring was initiated in 1992 was 19 μg/L. The most recent maximum concentration of CT detected in the A-Aquifer in September 2004 was 15 μg/L.

### 2.4.2 Upper 180-Foot Aquifer Groundwater Remedial Unit

The lateral extent of the affected groundwater in the Upper 180-Foot Aquifer is illustrated on Plate 3 based on the September 2004 data. The distribution of the COCs in this aquifer (CT) above aquifer cleanup levels (MCLs; Table 2) is contained within these lateral limits. There are two narrow, parallel plumes in this aquifer. The western CT plume in the Upper 180-Foot Aquifer is approximately 0.7 miles in length and 400 feet in width. The eastern CT plume in the Upper 180-Foot Aquifer is approximately 0.9 miles in length and ranges from 200 to 600 feet in width. These plumes are migrating toward the southeast from two apparent vertical conduits through the overlying FO-SVA clay. The western plume contains low concentrations of CT (typically below 1 μg/L) with slightly higher concentrations (2 to 3 μg/L) observed at MW-BW-26-180. The eastern plume contains slightly higher concentrations of CT than the western plume and range from the detection limit to over 5 μg/L. The western plume appears to emanate from a vertical conduit at or near the Mini-Storage well (built in 1996), although the sanitary seal appears to have been adequate to prevent cross-communication between aquifers. The eastern plume emanates from monitoring well MW-B-13-A (built in 1975), where the sanitary seal was either inadequate or somehow failed resulting in hydraulic communication between the A- and Upper 180-Foot Aquifers.

The vertical extent of the affected groundwater in the Upper 180-Foot Aquifer is assumed to correspond with its vertical thickness of about 60 feet, and is underlain by the Intermediate 180-Foot Aquitard, which is approximately 50 feet thick. Groundwater flows eastward and southeastward under largely confined conditions (without flowing into other aquifers) except within the southern portion of the OUCTP study area with hydraulic conductivity ranging from 100 to over 1,000 feet/day. The direction of flow appears controlled by the degree of hydraulic communication with the underlying Lower 180-Foot Aquifer, separated by the Intermediate 180-Foot Aquitard, where present. Where this aquitard pinches out, groundwater from the Upper 180-Foot Aquifer drains into the Lower 180-Foot Aquifer. The Upper 180-Foot Aquifer plume emanating from MW-B-13-180 migrated southeast toward the natural pinch-out of the underlying Intermediate 180-Foot Aquifer where is also entered the Lower 180-Foot Aquifer. The CT plume commingles with the Operable Unit 2 (OU2) TCE plume at this location (Plate 3).

As summarized in Table 2, the ACL for CT is 0.5 μg/L, and the maximum historic detected concentration in the Upper 180-Foot Aquifer since groundwater monitoring was initiated was 9.8 μg/L. The most recent maximum concentration of CT detected in the Upper 180-Foot Aquifer in September 2004 was 3.5 μg/L.

### 2.4.3 Lower 180-Foot Aquifer Groundwater Remedial Unit

The lateral extent of the affected groundwater in the Lower 180-Foot Aquifer is illustrated on Plates 4A/4B based on the September 2004 data. The distribution of the COCs in this aquifer (CT, 1,2-DCA) above aquifer cleanup levels (MCLs; Table 2) is contained within these lateral limits. There are two separate plumes in this aquifer. The northern CT plume in the Lower 180-Foot Aquifer is approximately 0.75 miles in length and 1,000 feet in width. The southern CT plume in the Upper 180-Foot Aquifer is defined by detections of CT at two monitoring wells approximately 0.5 miles apart that do not appear to form a continuous plume because CT has not been detected at monitoring wells in between these two wells. Continued downward CT migration through the same vertical conduits as have been identified in the FO-SVA and Upper 180-Foot Aquitard caused these two plumes to also develop within the Lower 180-Foot Aquifer. Active migration may be occurring at or near the Mini-Storage well where CT continues to migrate east/northeast toward the Salinas Valley, comprising the northern CT plume in the Lower 180-Foot Aquifer. This plume appears to terminate beneath the Marina Airport (previously known as the FAAF). The Upper 180-Foot Aquifer plume emanating from MW-B-13-180, however, migrated southeast toward the natural pinch-out of the underlying Intermediate 180-Foot Aquifer where it also entered the Lower 180-Foot Aquifer. The CT plume commingles with the Operable Unit 2 (OU2) TCE plume at this location and both contaminants appear to be migrating eastward toward the MCWD municipal wells. To date, CT has not been detected in any of these drinking water wells; however, TCE has been detected at MCWD Well No. 29 at concentration ranging from 0.51 to 0.81 μg/L, with the higher concentrations consistently being detected during late summer months.

The vertical extent of the affected groundwater in the Lower 180-Foot Aquifer is assumed to correspond with its vertical thickness of approximately 200 feet and has historically been and continues to be a significant source of potable water for the former Fort Ord and City of Marina area. Given an approximate aquifer thickness of 140 feet, the approximate hydraulic conductivity of the Lower 180-Foot Aquifer is 330 feet/day. Significant pumping from this aquifer since the 1940s, both locally and regionally, has resulted in seawater intrusion that extends within the northern portion of the OUCTP study area. Horizontal hydraulic conductivity values have been difficult to determine, given waste discharge limitations, but have been successfully simulated at 700 feet/day. This aquifer is the local equivalent of the regional 180-Foot Aquifer and passive groundwater elevation monitoring clearly illustrates seasonal and daily pumping cycles from irrigation wells located in the Salinas Valley, east of the OUCTP study area.

Pumping from the Salinas Valley has reversed the direction of flow within the Upper 180-Foot and Lower 180-Foot Aquifer. Beneath the site, groundwater in the Upper 180-Foot Aquifer flows to the southeast toward the apparent edge of the underlying Intermediate 180-Foot Aquitard where it then recharges the Lower 180-Foot Aquifer. Groundwater primarily migrates to the east in the Lower 180-Foot Aquifer but oscillates between a northeast direction in the summer (in response to increased pumping from the Salinas Valley) and a more southeast direction (locally in response to the MCWD Well Nos. 29, 30, and 31).

Vertical flow through the FO-SVA and Intermediate 180-Foot Aquitard is limited to locations at vertical conduits. Should these vertical conduits persist, groundwater may further migrate into the Lower 180-Foot Aquifer. As summarized in Table 2, the ACL for CT is 0.5 μg/L, and the maximum historic detected concentration in the Lower 180-Foot Aquifer since groundwater monitoring was initiated was 6.95 μg/L. The most recent maximum concentration of CT detected in the Lower 180-Foot Aquifer in September 2004 was 3.6 μg/L.

# 3.0 REMEDIAL TECHNOLOGY SCREENING

This section reviews and selects the remedial technologies that are retained for development of remedial alternatives based on site-specific conditions. Sections 3.1 through 3.3 below present the screening of no action/monitored natural attenuation, in situ remediation and groundwater extraction and treatment technologies, respectively; Section 3.4 summarizes the technologies retained for further consideration; and Section 3.5 presents a discussion of the technical and economic feasibility of remediating groundwater below aquifer cleanup levels (MCLs; Table 2) using the selected technologies. A summary of the technology screening is presented in Table 3.

CERCLA guidance for RI/FSs requires that, prior to development of site-specific remedial alternatives, there is an initial screening of the universe of remedial technologies that could be used to cleanup contaminated sites (*EPA, 1989b*). Initially, specific technologies or process options are evaluated primarily on the basis of whether or not they can meet the RAOs discussed in Section 2.1.

Potentially applicable remedial technologies were identified based on previous bench-scale and pilot treatability studies conducted during the RI (Volume I; Sections 3.8 and 3.9); experience in treating groundwater at the former Fort Ord; professional judgment; EPA and other remediation technology databases; and input from regulatory agencies. A range of technologies applicable to VOC contamination in groundwater for the OUCTP aquifers were identified and evaluated based on the initial criteria of effectiveness, implementability and relative cost as follows:

- *Effectiveness*—This criterion evaluates each technology based on its: proven ability to achieve cleanup goals, potential impacts on human health and the environment, and reliability with respect to site contaminants. Innovative technologies that have not been proven in full-scale operations but offer potentially substantial advantages in other areas (e.g., simplified operations) have been considered for alternative development.

- *Implementability*—This criterion evaluates the technical and administrative feasibility of implementing the technology at the site.

- *Relative Cost*—This criterion evaluates whether the capital and operating costs of implementing the technology are low, moderate or high as compared to other applicable technologies.

On the basis of this evaluation, technologies are screened, and those that are best suited to achieving the remedial action objectives identified in Section 2.1 are then combined to form remedial action alternatives for each of the three different plumes (A-Aquifer; Upper 180-Foot Aquifer; Lower 180-Foot Aquifer). These alternatives are presented in Section 4.0.

EPA's *Treatment Technologies for Site Cleanup: Annual Status Report (EPA, 2003)* documents the status and achievements, as of March 2003, of treatment technology applications at Superfund sites. The data in the report were gathered from Superfund Records of Decision (ROD) from fiscal year (FY) 1982 - 2002, Close-out Reports (COR) from FY 1983 - 2002, and project managers at Superfund remedial action sites. General trends in selection of groundwater remediation technologies are as follows:

- In situ technologies make up 42% of all source control treatments at Superfund remedial action sites. Since the inception of the Superfund program in FY 1982, the use of in situ source control treatments at these sites has been increasing to the current level of 45% in FY 2002. The total number of in situ groundwater treatment projects increased by 62% between 2000 and 2003. The most common in situ groundwater treatment technologies are bioremediation, permeable reactive barriers (PRB), air sparging, and chemical treatment. Air sparging decreased from 70% of in situ projects selected in FY 1996 to 9% in FY 2002. The percentage of RODs selecting in situ permeable reactive barriers has remained relatively consistent, below 10% for all years.

- RODs selecting P&T alone have decreased from about 80% prior to FY 1993, to an average of 21% over the last 5 years (FY 1998 - 2002). More than half of P&T systems use air stripping as a treatment technology. Other commonly used technologies include activated carbon adsorption, filtration, and metals precipitation.

- The general decrease in the selection of P&T remedies may be due to a variety of factors, including more widespread acceptance of innovative in situ groundwater treatment remedies; reduced operation and maintenance costs from using active in situ treatment technologies; reduced time to address risk and faster return of sites to beneficial uses by using active in situ treatment remedies; reduced costs by using monitored natural attenuation (MNA).

- The generally upward trend in the selection of in situ treatment may be due to several factors, including rapid growth and technological development within the industry based on performance data collected in recent years, and their ability to treat some media and contaminants that are difficult to remediate, such as dense nonaqueous phase liquid (DNAPL), chlorinated solvents, and fractured bedrock.

The following section describes the potentially applicable remedial technologies that can be implemented to manage or control contamination at a site (*EPA, 1989b*). After review of site-specific conditions at OUCTP, several general response actions were identified for the technology screening and development of remedial action alternatives for groundwater to meet the RAOs. The general response actions that are potentially applicable are:

- No Action with Monitored Natural Attenuation—Taking no action to remediate contaminated groundwater, with continued groundwater monitoring for COCs and Monitored Natural Attenuation parameters.
- Containment—Containing contaminated groundwater using barriers.
- Collection—Extraction of contaminated groundwater for aboveground (ex situ) treatment.
- Treatment—In situ (belowground) and ex situ (aboveground) treatment of contaminated groundwater.
- Disposal—Reinjection or recirculation of treated water back into the aquifer, or discharge to the surface or drainage systems.

This section describes the three different categories of remedial technologies under consideration that incorporate these general response actions: (1) no action with monitored natural attenuation; (2) in situ remediation, and (3) groundwater extraction and treatment. Various monitoring, containment, collection, treatment, and disposal options are identified and screened within each of the categories as applicable based on the evaluation criteria, and are eliminated or retained for further consideration for each of the three groundwater remedial units in the development of remedial alternatives as summarized in Section 3.4 and Table 3. The retained technologies are then evaluated in Section 3.5 in terms of the technical feasibility of remediating groundwater below aquifer cleanup levels if implemented. The economic feasibility of remediating groundwater below aquifer cleanup levels for each of the alternatives retained for detailed analysis is discussed in Section 5.0.

## 3.1 No Action with Monitored Natural Attenuation

No Action with Monitored Natural Attenuation is retained for further consideration for all three groundwater remedial units based on the following screening.

The No Action response does not involve implementation of any active treatment or remediation technologies. At some sites, no action may be appropriate as the selected remedy if (1) the results of the RI/FS indicate potential risks are not significant and remediation is not necessary to achieve RAOs, or

(2) aquifer cleanup levels can not be attained (i.e., full restoration of beneficial uses of the underlying groundwater is not technologically nor economically achievable within a reasonable period of time, and a modification to the cleanup standards or establishment of a containment zone—a limited groundwater pollution zone where water quality objectives are exceeded—is requested). In either of these cases, potentially remaining risks could be mitigated through institutional controls such as restrictions on the use of groundwater and continued monitoring of the plume to evaluate the concentration trends and extent of COCs and periodically reevaluate the protectiveness of the remedy. The monitoring program will establish "points of compliance", (i.e., groundwater monitoring wells within the plume) (Section 2.4; Description of Groundwater Remedial Units) and 'background wells' outside of the plume boundary for management of the residual groundwater contamination within OUCTP as part of the selected remedial actions for OUCTP that will include relevant components of Title 27 CCR regulations (e.g., Section 20405: Monitoring Points and the Point of Compliance, et. Seq.), described under Action-Specific Requirements, Section 2.2.3 for monitoring chemicals of concern (COCs) established in the Record of Decision.

The No Action alternative is required for detailed analysis as a remedial alternative for comparison to the other alternatives under CERCLA and the NCP. For purposes of analysis, this alternative would include continued groundwater monitoring for COCs under the existing monitoring well network and sampling and analysis program, as well as natural attenuation parameters as described below.

Monitored natural attenuation (MNA) can be defined as the use of naturally occurring contaminant degradation and dispersion processes to remediate contaminated groundwater; MNA must be demonstrated with environmental monitoring. The EPA defines MNA as "the reliance on natural attenuation processes to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by more active methods" (*EPA, 1997*). The natural processes that can affect the transport of organic contaminants and plume fate in all hydrologic systems include: biodegradation, advection, dispersion, dilution, sorption and desorption, volatilization and abiotic degradation processes, including hydrolysis.

An MNA program is one that assesses the contaminated environment and establishes its condition relative to natural attenuation processes. Research by the Commission on Geosciences, Environment and Resources indicates "natural attenuation is an established remedy for only a few types of contaminants, that rigorous protocols are needed to ensure that natural attenuation potential is analyzed properly, and that natural attenuation should be accepted as a formal remedy for contamination only when the processes are documented to be working and are sustainable." (*CGER, 2000*).

### *Effectiveness*

As discussed in the RI (Volume I; Section 3.7), the viability of MNA as a remedial strategy within OUCTP was assessed because of the stable but generally declining dilute VOC concentrations within OUCTP groundwater (in the part per billion range); indications that there is no longer a source of VOCs within the aquifer environment; and the widespread extent of the plumes within three sandy aquifers that could be difficult and costly to capture or contain and actively remediate.

CT and chloroform concentrations measured in the A- and Upper 180-Foot aquifers between March and December 2000 were specifically evaluated and molar ratios were calculated to assess the extent to which biological degradation of CT within the aquifer was occurring as evidenced by the presence of its daughter product chloroform. Additional groundwater samples were collected in April 2003 and analyzed for specific parameters that could indicate whether natural attenuation was occurring, including ferric and ferrous iron, sulfate, nitrate and nitrite, and dissolved gasses. Field parameters, including titrated alkalinity, oxidation/reduction potential (ORP) and dissolved oxygen (DO) were also collected during the four sampling periods. These data, along with the lithologic data collected from additional monitoring wells installed during and after these sampling periods were used to evaluate whether CT dissolved in groundwater is actively degrading under natural conditions within the OUCTP plume. Details of the natural attenuation investigation conducted in 2000 were published in the *Draft Final Natural Attenuation Summary Report, Carbon Tetrachloride Investigation, Former Fort Ord, California* (*Harding ESE, 2002*), and are summarized below in conjunction with recent data from natural attenuation sampling conducted in 2003.

The field program for natural attenuation sampling in 2000 included eleven monitoring wells in the A-Aquifer and seven monitoring wells in the Upper 180-Foot Aquifer. Based on the data collected during the March, June, September, and December 2000 natural attenuation sampling periods, and on lithologic data collected during and after the four sampling periods, natural attenuation appears to be occurring at the site in the A-Aquifer via microbial and physical processes. Inorganic and organic chemical results from the sampling periods indicate the presence of locally reductive environments conducive to microbial processes. Physical processes were indicated by groundwater flow patterns and molar ratios between CT and chloroform, particularly in the downgradient area of the plume at the wave-cut terrace. The overall increasing trend in the molar ratio between CT and chloroform observed along the axis of the plume indicates that (1) biodegradation processes may be present along the entire axis of the plume, but predominate near the suspected source area despite observing local areas with reducing conditions throughout the plume, and (2) physical processes appear to control the downgradient extent of the CT in the

A-Aquifer; however, they are inadequate to attenuate continued westward migration of the plume.

The inorganic data (observed nitrite, ferrous iron and methane) and organic data (chloroform) collected during the four periods of sampling also indicate that natural attenuation via microbial degradation is occurring to some extent in the Upper 180-Foot Aquifer of the CT plume under locally reduced conditions.

Biodegradation of the CT and other VOCs present in groundwater in OUCTP is not expected to occur at a significant rate as discussed in the RI (Volume I; Section 3.7). In areas of low concentrations of native or anthropogenic carbon (such as in sandy soils present within OUCTP), and dissolved oxygen (DO) concentrations greater than 1.0 milligrams per liter (mg/L), reductive dechlorination will not occur to an appreciable extent. DO concentrations are lower than 1.0 mg/L in locations within OUCTP; under such anaerobic conditions, CT has a degradation half-life of 19.6 to 120 days in groundwater. However, CT will not undergo significant biodegradation in the aerobic groundwater present in the OUCTP. Hydrolysis processes may contribute to a decrease in the mass of CT present in the groundwater over time.

Sorption and desorption processes will not have a significant effect on the OUCTP plumes because the results of the RI indicated a source of CT contamination is no longer in contact with the water table. Therefore, contamination throughout OUCTP is in the aqueous phase, and the plumes are no longer attached to their source areas.

Another possible method for demonstrating the degradation of a compound is to show decreasing concentrations over time. Section 4.0 of the RI (Volume I) indicated generally decreasing concentrations of CT may be a result of either degradation or dispersion or both. Some variability in the individual samples as groundwater moves could also cause the observed average CT concentration to increase, but not to a significant degree because historic maximum concentrations of CT have not increased significantly in most wells since sampling began in 1992.

***Implementability***

MNA would be easy to implement compared to other options that involve active remediation because it only requires continued monitoring and analysis of data under existing programs.

***Relative Cost***

MNA would have a very low relative cost compared to other options that involve active remediation.

***Results of Screening***

Given the dynamics of the plume, the generally declining concentrations of CT, and the indication that some natural attenuation processes are occurring within OUCTP, this technology would be an effective option for monitoring as opposed to active remediation; would be easy to implement; and would have a low relative cost compared to other options, and is retained for further consideration for all three groundwater remedial units.

## 3.2 In Situ Remediation

Enhanced biodegradation using injection of a carbon source such as lactate or similar compounds, and permeable reactive barriers are retained for further consideration for the A-Aquifer groundwater remedial unit only based on the following screening. In situ remediation technologies were eliminated from further consideration for the Upper 180-Foot and Lower 180-Foot Aquifers because they occur several hundred feet below ground surface where it would be technically and economically infeasible to install and maintain this type of system.

The main advantage of in situ treatment is that it allows groundwater to be treated ‘in place’ within the aquifer, with potentially significant cost savings when compared to GWET systems which must extract, process, store, treat, sample, and reinject or otherwise discharge large volumes of groundwater for the extended time period (typically several decades) it takes to removed the contaminated groundwater from the aquifer.

Several different in situ remedial technologies are screened for applicability in the A-Aquifer for the two process options of enhanced biodegradation and permeable reactive barriers. These technologies were eliminated from further consideration for the Upper 180-Foot and Lower 180-Foot Aquifers because they occur several hundred feet below ground surface where it would be technically and economically infeasible to install and maintain these types of systems.

### 3.2.1 Permeable Reactive Barrier

Permeable reactive barriers (PRBs) consist of permanent, semi-permanent, or replaceable reactive media that are installed in the subsurface within the aquifer to intersect the flow path of a contaminant plume. Typically they are filled with materials selected for their ability to remediate specific types of contaminants (*EPA, 1996*). As the contaminated groundwater moves passively through the treatment media, the contaminants are removed by physical, chemical and/or biological processes, including precipitation, sorption, oxidation/reduction, fixation, or degradation. Scrap iron metal, also called Fe(0) or zero-valent iron (ZVI), is the most common reactive media in the majority of pilot- and full-scale PRB implementations. Iron has the ability to reductively dehalogenate chlorinated VOCs in groundwater due to electron transfers, resulting in non-toxic end-products. In addition, long-term (five- to ten-year) performance data from several PRB installations indicate no significant decline in degradation performance over time, minimal porosity loss in the reactive media due to mineral precipitation, and expectations that the PRBs will continue to perform satisfactorily for at least another ten to fifteen years. Current expectations are that PRBs can maintain sufficient treatment performance for up to 30 years, but may require regeneration or replacement at some point in time.

### *Effectiveness*

Two types of PRBs—sorption and degradation barriers—could be used in treating the types of contaminants present in the A-Aquifer plume. Sorption barriers contain materials that remove contaminants from the groundwater flow by physical attraction (surface phenomena), chemical adsorption, or electrostatic attraction. Contaminants are fixed but not destroyed. Sorption barriers are typically filled with such materials as zeolites or activated carbon, and generally are not applicable for the depths and groundwater flow conditions found within OUCTP.

PRBs degrade VOCs as they pass through the zone of emplaced media; a variety of different iron materials are capable of abiotically degrading VOCs in this manner, such as zero-valent iron (ZVI), nano-scale or nickel-plated iron. In one study, five types of ZVI with different surface coating and particle sizes were evaluated in a bench-scale treatability study specifically for their ability to degrade high (parts per million [ppm] or mg/L) levels of CT; 9 % to 43 % of the CT was recovered as CF. CT was degraded completely by all types of ZVI with a half-life of as low as 0.5 hours. However, the actual residence time and wall thickness required to degrade concentrations of CT in groundwater from 15 parts per billion (ppb or µg/L) (maximum detected) to 0.5 ug/L (cleanup level) under fairly high hydraulic flow rates of 20 feet per day (ft/day) to several hundred ft/day would need to be further evaluated in bench- and pilot-scale studies. Nano-scale iron could also be injected in a slurry form in isolated locations for targeted source removal.

### *Implementability*

Installation of a PRB is typically only technically feasible to a depth of approximately 20 to 60 feet below ground surface (bgs) in sandy soils when standard trenching techniques are used. Since the groundwater plume at OUCTP occurs at depths greater than 60 feet within the A-Aquifer, an innovative installation method, such as azimuth controlled vertical hydraulic fracturing, would be required to construct the PRB.

With this method, the PRB is constructed from conventionally drilled wells installed along the PRB alignment.  A controlled vertical fracture is initiated at the required azimuth orientation and depth using a specialized frac casing installed in each well.  This hydraulic fracturing technology is capable of installing iron PRBs from 3 to 9 inches in thickness in a single treatment zone.  Multiple parallel treatment zones can be installed for PRBs that require a larger flowthrough iron thickness.  PRBs would need to be installed throughout the vertical thickness of the A-Aquifer and be keyed into the top of the silty clay aquitard (FO-SVA) to prevent the potential for underflow of contaminated groundwater beneath the PRB.  Impermeable sheet piles and slurry walls may be used to funnel a plume through permeable treatment sections, and are referred to as a funnel and gate system.  However, these would be difficult and costly to install at the depths needed to tie-in to the FO-SVA.

Preferential flow paths created by heterogeneous aquifer materials would make it difficult to effectively deliver the ZVI within the targeted areas requiring treatment.  Thus, the ability to achieve ACLs may be limited by these hydrogeologic conditions.  In addition, a pilot study would be required to further refine design parameters; select a preferred injection technique; evaluate hydrogeologic data to analyze potential impacts of groundwater chemistry (such as high TDS levels) on the long-term performance of the PRB; and determine the site-specific effectiveness of this technology.  Nano-scale iron could also be injected in a slurry form in isolated locations for targeted source removal, and would also require pilot study evaluation of its implementability and effectiveness.

### *Relative Cost*

Bulk materials costs for ZVI and other types of iron that can degrade CT are relatively low on a per-ton basis compared to other treatment media.  However, several PRBs would be required to effectively treat the large plume within the A-Aquifer (500 to 750 feet wide and 1.6 miles long), which would have a relatively high cost.  In addition, installation costs for a PRB using hydraulic fracturing are high compared to other in situ remediation systems.  However, the operations and maintenance costs of this technology would typically be considerably lower than those of a GWET or other in situ remediation system.

### *Results of Screening*

This technology would likely be effective for remediation of CT but would require multiple installations to remediate the entire plume; would be moderately difficult to implement from a technical perspective; and would have a high relative cost compared to other options, and is retained for further consideration for the A-Aquifer groundwater remedial unit because it would be an effective long-term option for in situ remediation of CT without extensive operations and maintenance (O&M) requirements.

### 3.2.2 Enhanced Biodegradation

Biodegradation naturally degrades many groundwater contaminants, but this process is often too slow to prevent contaminant migration. Bioremediation techniques stimulate the growth of microorganisms that consume contaminants to enhance naturally occurring biodegradation processes. When conducted in situ, this is generally accomplished by adding nutrients and/or electron donors, and by controlling dissolved oxygen and pH. Microorganisms adapted to the destruction of specific contaminants may also be applied to enhance the process, but have only been demonstrated to be effective in a small number of cases (*FRTR, 1997*). Additional details regarding the following discussion of the effectiveness, implementability, and relative cost of enhanced biodegradation of VOCs such as carbon tetrachloride in groundwater can be found in the report *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents* (*Parsons, 2004*).

***Effectiveness***

CT is generally resistant to aerobic biodegradation—a type of biodegradation that occurs due to the presence of oxygen as a food source for microbes, which then degrade certain chlorinated compounds such as VOCs. The groundwater aquifer environment within OUCTP is generally sandy with high flows, which means conditions within the aquifers are generally aerobic (oxygenated), and would not provide ideal conditions for biodegradation of CT. However, under non-aerobic (anaerobic) conditions where there is a lack of oxygen, biodegradation of certain VOC compounds such as CT does occur. Under anaerobic conditions, CT appears to be degradable with a half-life of 19.6 days (*Howard et al, 1991*). Therefore, in order to biodegrade CT within the OUCTP plume, it would be necessary to create an anaerobic (low oxygen) zone to degrade CT.

Anaerobic conditions can be created through the addition of electron donors such as methane or hydrogen sulfide gas, lactic acid (lactate), oil emulsions, molasses, hydrogen release compounds (HRC$^{®}$), or other compounds. Naturally occurring bacteria will use dissolved oxygen in the process of consuming these electron donors. Once the available oxygen has been consumed, other species of bacteria capable of using other electron acceptors will begin to dominate that can dechlorinate CT. Compared to aerobic degradation, anaerobic degradation generally involves additional intermediary steps, and the number of species capable of anaerobic biodegradation are fewer. This results in anaerobic environments being less robust and producing more recalcitrant byproducts than aerobic biodegradation. However, anaerobic in situ bioremediation has been used successfully at numerous sites and aerobic biodegradation has not been demonstrated to be occurring to an appreciable degree within OUCTP to justify trying to enhance its effectiveness. In the natural environment, the degradation of a compound may lower the concentration of that compound to a threshold concentration, below which biodegradation will not occur. At concentrations less than the threshold level, organisms which are otherwise capable of degrading a compound cannot receive sufficient energy from that degradation reaction to continue to function. The MCL for CT is 0.5 ug/L, and it is quite possible that this standard is less than the threshold concentration needed for degradation to continue to take place.

There are a number of different process options for enhancing anaerobic biodegradation of contaminated groundwater through adjustment of the oxygen content of the aquifer environment and amendment of microbial growth substrates (also referred to as carbon sources, food sources, and electron donors). The biodegradation process can be enhanced by the addition of biodegradable organic substrates, resulting in the production of less-chlorinated intermediate products. Common growth substrate additives that promote biodegradation include alcohol (e.g., methanol or ethanol), sugars (e.g., glucose or molasses), fatty acids (e.g., lactic acid, sodium or ethyl lactate; acetic acid, or vinegar), emulsions (e.g., edible oils/surfactants) or natural gases (e.g., methane or hydrogen), as well as proprietary compounds and mixtures of enzymes, nutrients, stimulants, etc.

For the purposes of this screening, a proven subset of the many different types of electron donors or substrates were evaluated and the one that best met the evaluation criteria was selected for detailed analysis as a remedial alternative for the A-Aquifer. However, it is assumed that a more detailed assessment of the exact type of formula that would work the best for remediating COCs within OUCTP will be undertaken during the remedial design phase of this project if in situ enhanced biodegradation is selected as the preferred remedial alternative for implementation.

### *Gaseous Nutrient Injection*

There are several different process options available for physically increasing the amount of oxygen in the aquifer in order to support aerobic biodegradation (e.g., injecting air), or conversely, for decreasing oxygen to support anaerobic biodegradation (e.g., injecting methane gas). Gaseous nutrient injection is typically used in conjunction with the remedial technologies of air sparging, bioventing, biosparging and bioslurping. Vapor extraction is often used in conjunction with gaseous nutrient injection, with the most common added gas being air. In the presence of sufficient oxygen, microorganisms convert many organic contaminants into carbon dioxide, water, and microbial cell mass. In the absence of oxygen, organic contaminants are metabolized to methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas. Another gas that may be added is methane, which enhances degradation by cometabolism, a process by which the bacteria consume the methane and produce enzymes that react with the organic contaminants to degrade it into inorganic minerals. It is possible subsurface injection of gases below the water table can induce groundwater flow, therefore, it may be necessary to use a pump and treat system in conjunction with gas injection for hydraulic control. In addition, gaseous nutrient injection would be difficult to implement at an effective air-water ratio that would reduce VOC concentrations already in the low parts per billion (ppb) range by an order of magnitude (e.g., to below ACLs) as is required at this site, and it would require extensive piping and gas storage and delivery systems to remediate such a large plume, and would and be difficult to implement from explosive gas safety and aesthetic perspectives.

### *Hydrogen Release Compound (HRC®)*

HRC® is a proprietary food grade polylactate ester that upon being deposited into the subsurface slowly degrades to lactic acid. Lactic acid is then metabolized to release hydrogen, which in turn is utilized by the microorganisms capable of reductive dechlorination of the VOCs in groundwater. By providing a long-lasting, time-release hydrogen source to the environment, the effectiveness of contact, containment, and remediation of the chlorinated VOC plume is significantly increased. HRC® is a flowable liquid which is pressure-injected using standardized direct push/drilling technologies. Anaerobic biodegradation of chlorinated VOCs (e.g., CT, PCE and TCE) requires highly reducing conditions to stimulate anaerobic bacteria to dechlorinate the contaminants. HRC® is designed to provide a carbon or electron donor source to create the conditions necessary to enhance anaerobic biodegradation.

An approach to the application of HRC® at OUCTP was based on the use of HRC® at other sites, and site specific information input into the design software developed by Regenesis for design of remediation systems utilizing HRC® injection. Regenesis has developed and distributed HRC® Design Software to aid experienced environmental professionals in developing an approach and conceptual design for accelerated natural biodegradation projects. The Regenesis software does not provide a single correct solution to a given problem, but rather allows for multiple strategies to be evaluated on the merits of treatment objectives, cost, risk, site constraints, and other environmental issues. The resulting approach, based on typical site conditions and the HRC® software model results, would be to construct multiple barriers each consisting of two rows of injection points that extend across the width of the plume within the A-Aquifer. Approximately 140 HRC® injection points would be required to construct each individual barrier, and 700 pounds of HRC® would have to be injected at each point in order to provide adequate remediation of COCs within the aquifer for a period of 2 years. In addition, this technology would not be practical to apply at the toe of the plume where the hydraulic conductivity is much higher and would require 12,000 pounds of HRC® be injected at each point in order to provide adequate remediation of COCs within the aquifer for a period of 2 years. Because HRC® is approximately 8 times the cost per pound than other electron donor solutions such as lactate or molasses, and significant volumes would be required based on initial estimates for the type of aquifer and concentrations of COCs within OUCTP, it is not considered to be economically feasible to evaluate use of this product further at this time.

### *Emulsion-Based Food Amendments (Edible Oils, Surfactants, etc.)*

Food-grade oils can be adapted as water-miscible emulsions with controlled droplet size to function as organic substrates in VOC-contaminated aquifers. The emulsion is prepared using food-grade edible oils and surfactants and then distributed throughout the treatment zone using conventional wells or temporary direct-push points. A portion of the oil becomes trapped within the soil pores leaving a residual oil phase to support long-term anaerobic biodegradation of the target contaminants. Biodegradation of contaminants entering the barrier will be enhanced by the slow dissolution of the trapped residual oil phase. The spatial distribution of the oil emulsion in the aquifer and the impact of emulsion injection on the aquifer permeability and groundwater flow paths is not well understood, and would need to be carefully considered. Distribution of this more viscous amendment throughout the injection area does not occur as readily as with unbuffered sugar-based food amendments; therefore, it would be important to ensure it is injected carefully within the stratigraphic units where CT occurs so that it is distributed throughout the area of contamination.

Proprietary Edible Oil Substrates (EOSs) are available that distribute and immobilize edible oils in the subsurface for aquifer remediation. Data has shown pure liquid oils are difficult to effectively distribute in the subsurface and can result in a substantial loss of permeability. However, properly prepared emulsions can be distributed significant distances from the injection point without a substantial loss of aquifer permeability. This process can be used to stimulate anaerobic biodegradation of chlorinated VOCs. However, there is evidence that VOCs in groundwater will partition into the oil where they remain unavailable for biodegradation, artificially reducing concentrations in groundwater without actually destroying the VOCs. Once EOS has been injected, it can last up to 3 years. EOS is effective in heterogeneous aquifers and can be injected with direct push technologies, wells or other technologies. The two limitations are aquifers with very high flow rates or a lack of the appropriate microorganisms. Because OUCTP aquifers have high flow rates, and the spatial distribution of the oil emulsion in the aquifer and the impact of emulsion injection on the aquifer permeability and groundwater flow paths is not well understood, it is not considered further at this time.

### *Molasses*

The injection of molasses into the subsurface induces anaerobic microbial activity that drives the system into increasingly lower redox (Eh) conditions and associated degradation mechanisms. The advantages of molasses are that it is readily available, it contains many important trace nutrients, it is easily metabolized by a wide range of microorganisms, and it is a food grade material that can be injected into the groundwater with a low potential for water quality impacts from the molasses itself. However, sugars such as molasses are consumed by the microbes relatively quickly and are not long-lasting in the aquifer environment, and would frequently need to be replenished (reinjected), which would increase the system operations and maintenance requirements. In addition, enhanced biodegradation via injection of molasses has been implemented in a pilot study at the former Fort Ord for a similar dilute VOC plume, and the results of the study were inconclusive due to unexpectedly low concentrations of VOCs within the pilot study area.

### *Effectiveness of Site-Specific Treatability Study Electron Donors*

As described in Sections 3.8—3.9 and Appendix H of the RI (Volume I), site-specific bench-scale and pilot-scale biotreatability studies were conducted to determine the viability of enhanced biodegradation as a remedial strategy for OUCTP. Results of the Phase I microcosm study indicated that groundwater in the A-Aquifer contained bacteria capable of degrading CT under anaerobic conditions that favor reductive dechlorination mechanisms (e.g., electron donors, strong negative ORP, and nutrients, etc., were present). These results justified a second phase of testing, including an evaluation of the effectiveness of different electron donors (carbon sources) that could potentially enhance biodegradation rates of CT.

The Phase II bench scale test included the evaluation of enhanced biodegradation from a groundwater sample inoculated with three different carbon sources: sodium lactate, molasses, and soybean oil. The goals of this bench scale test were to (1) determine which electron donor would be the most effective at reducing CT concentrations, (2) determine whether supplemental nutrients would be necessary to effectively enhance CT biodegradation under actual field conditions when injected in the OUCTP aquifer, (3) provide an estimate of carbon source (donor) concentrations necessary to effectively induce enhanced biodegradation conditions in the field, and (4) provide an indication of the carbon source residence time necessary to initiate biological activity and sustain effective CT biodegradation. Of the three carbon source amendments, sodium lactate (lactate) appeared to have the most effectiveness in reducing CT concentrations, and was selected as the amendment for injection in a field phase bio-treatability pilot study at OUCTP.

To determine whether lactate would effectively lead to the dechlorination of CT in the A-Aquifer, a cluster of nine monitoring wells (PS-CT-01 through -09) were installed to fully penetrate the A-Aquifer surrounding a recirculation well (PS-CT-recirculation) just upgradient of MW-BW-23-A (Plate 2A). The recirculation well was designed with two screens within the A-Aquifer to allow lactate to be injected in one screen, forced into the formation, and withdrawn from the other, such that a hydraulic cycle would be established with lactate saturating the A-Aquifer approximately 15 feet radially from the recirculation well.

After lactate injection within the A-Aquifer, groundwater sampling and analysis for COCs and biodegradation parameters, as well as dissolved oxygen readings to measure the production of oxygen via biodegradation, were conducted at approximate 6-week intervals. The addition of lactate during the field-scale pilot study resulted in the essentially immediate and lasting reduction in CT concentrations in monitoring wells proximal to the recirculation well. For instance, initial concentrations at PS-CT-02, located approximately 15 feet west of the recirculation well, ranged from 3 to 4 μg/L at three discrete depths within the screen interval prior to the injection of lactate. Samples collected two months later indicate CT was not detected at the middle and bottom sampling positions, where lactate had been injected, whereas concentrations remained elevated (5.3 μg/L) at the upper position. CT concentrations at the injection well itself initially ranged from 4 to 4.5 μg/L but were non-detect following the recirculation of lactate. Concentrations at PS-CT-01, -03, and -05, the next closest monitoring wells to the recirculation well, also indicated consistent decreases in CT concentrations, especially in the downgradient direction.

The reduction in nitrate, ferric iron, and sulfate concentrations all indicate that denitrifying, iron-reducing, and at least sulfur-reducing concentrations (if not methanogenic) conditions were attained at least locally within the pilot study area. Methanogenesis is indicated by the detection of methane at PS-CT-IW (up to 1.7 mg/L) in June and July 2004 and a J-qualified detection at PS-CT-04 in July 2004; however, a widespread or enduring level of methanogenic conditions is not apparent. DO values indicate that the effects of lactate injection to the A-Aquifer are long-lasting and that the re-circulation method of injection produces desirable results with a radius of influence of at least 20 feet cross-gradient and up to 60 feet downgradient.

***Implementability***

In summary, to remediate CT using in situ biotechnology in portions of the OUCTP aquifer, it would be necessary to turn these areas into anaerobic zones. Doing this to large sections of the aquifer would involve the injection of correspondingly large amounts of electron donor solutions. Due to the low levels of contamination present, it is possible that a significant portion of the electron donor addition would be used to remove oxygen from the aquifer and not be used exclusively for reductive dechlorination. However, the site-specific bio-treatability study indicated significant increases in DO and decreases in CT concentrations using lactate. Creating large anaerobic zones would have a substantial impact on the subsurface environment and greatly alter local geochemical balances. Full scale applications of in situ enhanced biodegradation systems, although generally less expensive than GWET systems, have experienced numerous operational difficulties, such as aquifer fouling. This potential will be further evaluated during the remedial design phase if this technology is selected for implementation; reintroduction of oxygen downgradient of the treatment area to restore the aerobic balance of the aquifer could be considered if potential impacts are identified (e.g., using air sparging/recirculation wells).

Installation of lactate injection and recirculation wells would be technically feasible and moderately easy to implement throughout the majority of the A-Aquifer as demonstrated in the pilot study conducted at the site. Mobile, modular lactate injection and recirculation units could be located at each injection area for the duration of the injection event (approximately one week) and then be moved to another injection area, providing flexibility in injecting lactate wherever monitoring results indicate CT concentrations exceed cleanup levels. At the toe of the plume where permanent injection wells would be difficult to install within developed portions of the City of Marina, lactate could be pressure-injected using standardized direct push/drilling technologies (‘direct-push technology; i.e., a one-time injection of lactate via a temporary boring) could be used.

It should be noted that the effective duration of lactate in maintaining reductive dechlorination conditions within the A-Aquifer has not yet been determined because long-term data is not yet available from the pilot biotreatability study. However, DO values in the pilot study monitoring wells (Plate 2A) have consistently remained at very low concentrations favorable for enhanced biodegradation for over eight months since lactate was injected. In addition, Plate 5 depicts the predicted extent of the A-Aquifer CT plume one year after lactate injection based on the results of the modeling simulation, and shows that the CT plume in the A-Aquifer would already be broken up into several separate and smaller plumes. Although the modeling results are based on conservative assumptions that a single injection of lactate would only reduce the CT plume to the extent shown in the model after one year with no further degradation (thus lactate may have to be reapplied to the areas of high CT concentrations every year for a period of 15 years to fully remediate the A-Aquifer as shown on Plate 5), it is expected that each of the separate plumes present at the end of one year would continue to degrade and naturally attenuate with time in this oxygen-reduced environment.

Given the conservative nature of the simulation, and the limitations associated with the grid size assumed in the simulation modeling, especially near the toe of the plume, it is likely that far less time would be required to remediate the A-Aquifer. Based on the fact that DO values in the pilot study monitoring wells (Plate 2A) have consistently remained at very low concentrations favorable for enhanced biodegradation for over eight months since lactate was injected, it is reasonable to assume these conditions would be maintained within the A-Aquifer for a period of several years.

For the purposes of evaluating and costing alternatives, it is anticipated based on the results of the pilot study that lactate would continue to be effective at enhancing anaerobic biodegradation within the aquifer for a period of 2.5 years before lactate needs to be reinjected to enhance anaerobic biodegradation of the residual plume. This assumption will be assessed and modified if necessary to identify alternative carbon sources during the remedial design if this alternative is selected for implementation, at which point more data on the long-term effectiveness of lactate in the pilot study area becomes available.

#### *Relative Cost*

Bulk materials costs for lactate solutions that can degrade CT are relatively low on a per-pound or -gallon basis compared to other treatment media. However, several injection locations would be required to effectively treat the large plume within the A-Aquifer (500 to 750 feet wide and 1.6 miles long), which would have a moderately high cost depending on how long-lasting the lactate is within the aquifer and hence, how often it may need to be reinjected. In addition, installation costs for injection and recirculation wells and direct-push installation would be significant, but not as high as for installation of ZVI to create a PRB using hydrofracturing. However, the operations and maintenance costs of this technology would be considerably lower than those of a GWET or continuous injection in situ remediation system.

#### *Results of Screening*

This technology would likely be effective for remediation of CT but would require multiple injection locations with repeated injections every few years for an unknown period to remediate the entire plume; would be moderately difficult to implement from a technical perspective; and would have a moderate relative cost compared to other options, and is retained for further consideration for the A-Aquifer groundwater remedial unit because it would be an effective long-term option for in situ remediation of CT without extensive O&M requirements.

## 3.3 Groundwater Extraction and Treatment

Groundwater extraction and aboveground treatment via granular activated carbon or air stripping and reinjection is retained for further consideration for the A-Aquifer groundwater remedial unit based on the following screening. Similarly, groundwater extraction and aboveground treatment in the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS) is retained for further consideration for the Upper 180-Foot Aquifer. GWET was eliminated from further consideration for the Lower 180-Foot Aquifer because (1) it would impact the hydrologic stability of this aquifer that is used for drinking water by the City of Marina; (2) the plume is limited in extent and has not impacted drinking water supply wells; and (3) its presence is due to vertical conduits identified in the RI (Volume I) that will be destroyed that are allowing dilute concentrations of VOCs in groundwater in the upper aquifers to travel into this aquifer. However, well-head treatment via granular activated carbon or in-line air stripping within the water supply well system is retained for further consideration if these conditions change and statistically significant increases in the concentrations of COCs or extent of the plume occur in the future.

Groundwater extraction and treatment (GWET) technologies have an extensive history of being used to contain groundwater contamination plumes, particularly in highly permeable aquifers such as are present at the former Fort Ord and within OUCTP. However, even a properly designed GWET system may require a long time, on the order of decades, to restore a contaminated aquifer. Construction and annual operating costs for GWET systems are moderately high compared to in situ treatment technologies. By changing pumping rates (and if necessary adding wells), GWET can provide flexibility in dealing with changing site conditions.

The discussion below evaluates technologies for removing contaminated water from the aquifer for aboveground treatment, treating the water, and disposing or discharging the treated water.

### 3.3.1 Groundwater Extraction Technologies

Groundwater extraction technologies bring groundwater to the surface where it can be treated to remove contamination. Potentially applicable technologies include vertical extraction wells, horizontal extraction wells, and drains or trenches.

#### *Vertical Extraction Wells*

Vertical extraction wells are constructed by drilling a vertical borehole to a selected depth and installing a well with a slotted screen across the contaminated zone. The diameter of the well can vary and is determined from the desired pumping rate, the pumping equipment necessary to achieve this rate, and the anticipated drawdown. Extraction wells with diameters as large as 8 inches have been installed at the former Fort Ord. Generally the pump is located within the well, inside or above the well screen. Vertical extraction wells are somewhat prone to fouling, depending on aquifer geochemistry. However, the sandy, high-flow aquifers typical of the former Fort Ord are not prone to fouling. Vertical extraction wells have been used extensively at other GWET operable units at the former Fort Ord, and in the pilot biotreatability study conducted in the A-Aquifer at OUCTP, and fouling problems have been minimal and manageable.

A key consideration for extraction systems is the location where water will be extracted from the aquifer. In general terms, extraction can take place either at the leading edge of the plume or within the plume footprint. For most plume geometries, leading edge extraction offers the most cost effective method of plume containment because the system relies on the ambient flow conditions to move contamination to the capture zone. Conversely, it is the most expensive option when it is rated on the basis of cost per unit Mass of Contaminant removed. This is because the extracted water generally has low contaminant concentrations. Wells are positioned to capture all known contamination as the plume flows downgradient, but if the plume trajectory changes, it may bypass the well field or become smeared across the aquifer. In-Plume wells are not focused on containment but on maximizing contaminant mass reduction in the areas of greatest contamination. In-plume extraction wells shorten the time required for remediation by reducing the distance contaminants travel to the pumping well.

The use of leading edge extraction wells and in-plume extraction wells, and a combination of both were considered for each area of contamination in the OUCTP aquifers in the groundwater modeling conducted in the RI (Section 9.0 and Appendix F; Volume I). Remedial action objectives and potential environmental impacts caused by water table drawdown were the driving forces behind extraction well location decisions. The suitability of individual extraction locations (in three dimensions) were evaluated using groundwater modeling.

### *Horizontal Extraction Wells*

The use of horizontal extraction wells installed with horizontal or directional drilling techniques allows for wells that are geometrically aligned with contamination locations and trajectories. Such an alignment can minimize the number of wells that need to be installed. Horizontal drilling was developed to install utility lines under existing structures. For environmental restoration, it allows for well installation beneath surface structures that obstruct the ground surface such as building foundations, roads. Such obstacles are not a major concern in remediating the OUCTP plumes throughout the majority of the plume, but may be a factor at the toe of the plume within developed portions of the City of Marina. Beyond a depth of about 20 feet bgs, larger drilling equipment would be required and costs would increase exponentially with depth. At the depths of concern within the OUCTP, horizontal extraction wells are not feasible at this time.

### *Drains or Trenches*

Drains or collector trenches are horizontal structures designed to collect water. Unlike horizontal extraction wells, drains are installed in a trench, which limits the potential installation depth to approximately 20 feet bgs. They are most effective in capturing water where shallow plumes are migrating in medium to low permeability soils (*ANG, 1992*). In high permeability soils, it is difficult to maintain uniform capture along the length of the drain. The majority of the A-Aquifer and lower OUCTP plumes occur below 20 feet bgs and flow primarily through highly permeable sands; therefore, they are too deep for drain installation to be feasible.

***Results of Screening***

Vertical extraction well technology is proven and effective within the former Fort Ord; could be easily implemented in the A-Aquifer and Upper 180-Foot Aquifers; would have a moderate relative cost; and will be considered in the groundwater modeling and design of GWET systems for the OUCTP A- and Upper 180-Foot Aquifers.

### 3.3.2 Groundwater Treatment Technologies

Air stripping and activated carbon adsorption are both applicable, proven effective remedial technologies for the low VOC concentrations in groundwater within OUCTP and are described below. Other technologies that utilize thermal, chemical, biological, or physical processes to treat groundwater aboveground would not be technically or economically feasible for the low-level (parts per billion) concentrations of CT and other VOCs within OUCTP (*FRTR, 1997*).

### 3.3.2.1 Air Stripping

Air stripping is commonly used to remove volatile components from water. For groundwater remediation, air stripping is typically conducted on extracted groundwater in an aboveground treatment unit. Although this technology can also be implemented within extraction or recirculation wells (in-well stripping), it is not considered feasible for implementation for the deep depths and/or large lateral extents of the plumes within OUCTP. Aboveground air strippers typically utilize packed tower or tray tower configurations. In both systems water enters the top of the treatment vessel and air is injected from the bottom. This countercurrent flow optimizes the driving force for mass transfer across the length of the stripper. A packed tower will typically have spray nozzles at the top to distribute the influent over a packing material consisting of variously shaped balls, rings, or saddles. The packing material can be constructed from a variety of materials and is designed to maximize the effective surface area of water passing through the tower and to maximize air turbulence. The inside wall of the tower typically has several redistributors to prevent the water from simply running down the wall. A fan forces air countercurrent to the liquid flow, and a sump at the bottom of the tower collects the treated water. In a tray tower, water flows across the trays and air passes up through the water on the trays. Because air strippers create a highly oxidizing environment, they are particularly susceptible to fouling. In a packed tower, fouling may fuse individual pieces of packing together and require cleaning or replacement of the packing. Trays are less susceptible to fouling and are easier to clean if fouling does occur.

### *Effectiveness*

Henry’s Law constant and solubility are often used as a measure of the potential effectiveness of air stripping on a particular contaminant. Generally, organic compounds with Henry’s Law constants greater than 0.01 atmosphere-millimol (atm-m/mol) are considered amenable to air stripping. For a given Henry’s Law constant, the lower the compound’s solubility, the more amenable it is to air stripping. A review of Henry’s Law constants and solubilities for CT and other VOCs in groundwater within OUCTP suggests that air stripping is an appropriate technology for removal of CT. The Henry’s Law constant for CT at 20 degrees Celsius is 0.024 atm-m /mol, and the solubility is 800 mg/L.

When successful, air stripping transfers contaminants from the aqueous to the vapor phase. Subsequent vapor phase activated carbon filtration may be required to capture the vapors from the air stripper. Vapor phase carbon has a greater capacity for holding contaminants than liquid phase activated carbon. Removal efficiencies of 99 percent are possible for stripping towers that have 4.6 to 6 meters (15 to 20 feet) of packing and are treating highly volatile compounds, such as CT. Removal efficiencies will be lower during periods of lower temperatures. Due to lower effective surface areas, tray towers generally have lower efficiencies. Removal efficiency can be improved by operating strippers in series, increasing the air-to-water ratio, or by heating either the air or water.

### *Implementability*

Several factors may affect the implementability of air strippers. Neighbors may object to both the noise generated by rapidly moving large volumes of air and the vessels’ height. Low-profile tray towers are available, but also generate considerable noise. Sound-muffling housing can be constructed around the air stripper if necessary to reduce noise. Subsequent vapor phase activated carbon filtration of the air stripper effluent may be required to capture and reduce concentrations of VOCs (referred to as a ‘polishing’ phase) before discharging to the atmosphere depending on concentrations and regulatory requirements.

### *Relative Cost*

Air strippers have a low to moderate cost to purchase compared to other technologies, but are easy to maintain so have lower operations and maintenance costs.

***Results of Screening***

Air stripping, particularly using tray towers, is efficient for removing CT at low concentrations; would be moderately easy to implement because air stripper units that can be easily maintained are readily available; would have a low to moderate relative cost compared to other options, and is retained for further consideration.

#### 3.3.2.2 Activated Carbon Adsorption

Activated carbon adsorption removes organic materials from water or vapor streams by adsorption, the attraction and accumulation of one substance on the surface of another. Activated carbon is manufactured from carbonaceous material such as coal or wood. The material is initially pyrolized, burned in a limited oxygen environment, and then oxidized at higher temperatures to create a very porous structure (*Peavy et al., 1985*). This second step, referred to as activation, produces a network of submicroscopic pores in which adsorption takes place. A single pound of activated carbon may contain an effective total surface area of over 100 acres, allowing it to treat large quantities of organic liquids and vapors under ideal conditions.

As water passes through porous granules of carbon, contaminant molecules are attracted to the surface of the pores and held there by weak chemical, physical or electrostatic forces, or a combination of these forces. Chemical bonding, when it occurs, is relatively irreversible. The attractive physical forces (a type of Van der Waals force), are the same forces responsible for surface tension and condensation of vapors into liquids. Electrostatic attraction increases as the ion charge increases and as the hydrated ionic radius decreases. When held by either physical or electrostatic attraction, the adsorbate is not fixed to a specific site and the adsorption is reversible. When an adsorber system runs beyond breakthrough, more weakly adsorbed components can be desorbed into the effluent. Resulting concentrations may exceed influent concentrations. To ensure that no contamination is present in the effluent, carbon treatment groundwater remediation systems are typically installed with two or more vessels in series so that as the first vessel (lead adsorber) nears its breakthrough capacity, there is reserve adsorption capacity maintained in the second vessel (polishing adsorber).

Initially, the contaminants are adsorbed onto carbon in the upper portion of the lead bed. As this top layer of carbon becomes saturated, adsorption takes place lower in the bed. Eventually all the carbon in the lead adsorber becomes saturated and the contaminant concentration in the effluent of the adsorber increases until it approaches or equals the influent concentration (breakthrough). Alternately, breakthrough may be defined as the effluent concentration from the lead adsorber equal to or greater than some discharge standard. Operational samples are generally taken between the pair of carbon vessels. Once breakthrough has occurred in the first vessel, the carbon in that vessel must be replaced and the flow redirected so that the polishing adsorber becomes the lead adsorber and the former lead adsorber (with fresh carbon) becomes the polishing adsorber. This method of operation ensures that the polishing adsorber always contains a reserve of adsorption capacity.

Spent carbon is routinely returned to the manufacturer for regeneration. The process of regeneration results in the destruction of organic contaminants by exposing the spent carbon to a high temperature oxygen-deficient environment. The organic carbon partition coefficient is commonly used as an indicator of a chemical's affinity for adsorption onto activated carbon. The organic carbon partition coefficient is defined as the ratio of the concentration of organic chemical adsorbed onto organic matter to the equilibrium concentration of the same chemical in the aqueous phase. CT and the other VOCs in the OUCTP plumes are amenable to carbon adsorption, with CT having an Organic Carbon Partition Coefficient (Log Koc) of 2.35 cubic centimeters/gram.

#### *Effectiveness*

Carbon treatment units have been used to effectively treat contaminated groundwater at the former Fort Ord. Wellhead treatment systems can also use liquid-phase carbon adsorption. Carbon treatment systems are particularly well suited for conditions in which concentrations in the influent are relatively low so that carbon requirements are low. In addition, this technology can be used to treat off-gas vapors from air strippers or other groundwater treatment effluents as a polishing step of the vapor phase to aid in meeting air discharge requirements.

#### *Implementability*

Carbon systems are readily available and could be implemented for any of the groundwater contaminant plumes in the OUCTP study area. When contact time is sufficient, carbon adsorption is capable of removing organic contaminants to nondetectable levels. Carbon adsorption is a feasible treatment process for CT and will be considered for alternative development. A wide variety of activated carbon adsorption vessels are commercially available.

Modular, mobile carbon treatment systems are also available and could be used for wellhead treatment at individual wells. These units are adaptable to the surrounding terrain and can be placed close to wells, minimizing extraction pipeline lengths and reducing GWET system construction requirements. This option could be considered in locations where it would be difficult to install an extensive aboveground piping conveyance system between extraction wells that are widespread across the large plumes in OUCTP that are separated by roads or other structures, and in situations where treatment at existing supply wells is required due to plume migration. Mobile treatment systems can be trailer or skid mounted. If commercial electric power is unavailable, extraction pumps could be powered by a diesel electric generator.

The treatment system itself could be installed in the immediate vicinity of the extraction well. Treated water would be discharged into the water supply system. Treatment would continue in each location until either the remedial objectives had been met, or until a location suitable for this type of treatment with higher levels of contamination was located. Multiple systems could be used in different locations, depending on the level of effort required to meet remedial objectives.

Mobile carbon treatment could be prioritized for in-plume mass reduction efforts. This technology is less appropriate at leading edge (containment) locations because of the longer treatment periods involved. Pumping rates would be limited by system size. The system would have high sampling costs because it is anticipated that an initial influent sample and weekly samples taken between the carbon beds would be required. Additional influent samples would be required on a monthly basis. During operations, mobile systems are also more manpower intensive than permanent facilities and require operator attention on a daily basis for such tasks as generator refueling.

There are several advantages to mobile carbon treatment systems. Contamination in the OUCTP study area is highly dispersed. A mobile treatment system can focus remediation efforts on the most contaminated areas and achieve mass reduction. The systems have low capital costs and could potentially be rented from vendors and returned when no longer needed. The greatest benefit of mobile carbon treatment systems is their flexibility. Because of their ability to quickly focus on the areas of highest contamination and their flexibility in adapting to changing situations, they will be considered in developing remedial alternatives.

### *Relative Cost*

Carbon treatment vessels are moderately expensive. Their capacity for holding contamination is a function of contaminant concentration, the presence of other molecules of similar size, the consistency of the influent stream over time, and the adsorbability of the contaminant. More than one vessel is required (typically two or more vessels are installed in series) and must be changed out and regenerated on a regular basis, with regular sampling to detect breakthrough of COCs from the vessel and the need for changeout and offsite regeneration.

***Results of Screening***

Given the low level (ppb) concentrations of CT, this technology would be an effective option for aboveground treatment; would be moderately easy to implement because carbon treatment vessels are readily available; would have a moderate to high relative cost compared to other options, and is retained for further consideration for all three groundwater remedial units.

### 3.3.3 Groundwater Circulation and Disposal Technologies

Groundwater circulation and disposal technologies return groundwater to the aquifer or discharge to surface water, storm drain or other locations after it has been treated to remove contamination. Potentially applicable technologies include reinjection wells, recirculation wells (including air sparging/in-well stripping wells), infiltration galleries or trenches, and surface water discharge.

***Reinjection Wells***

Reinjection wells are vertical wells capable of injecting water directly into the saturated portion of the aquifer. Control valves can be adjusted based on data feedback from flow meters to control the rate of reinjection.  Controlling discharge locations and ratios provides flexibility in the hydraulic control of the plume.  Reinjection wells can also be used to minimize drawdown of the groundwater table.  Vertical reinjection well technology is proven and effective within the former Fort Ord; could be easily implemented in the A-Aquifer and Upper 180-Foot Aquifers; would have a moderate relative cost; and will be considered in the groundwater modeling and design of GWET systems for the OUCTP A- and Upper 180-Foot Aquifers.

***Recirculation and Sparging Wells***

Recirculating well technology is a recently developed process used primarily for the removal of VOCs in groundwater.  Pilot tests of this technology at OUCTP have been run and proven effective and implementable during the bio-treatability lactate injection pilot study within the A-Aquifer.  The technology creates a zone of vertical groundwater recirculation in the vicinity of the treatment well as a result of the extraction and reinjection of groundwater at different elevations within the same well. Under some circumstances, the creation of vertical groundwater recirculation may actively flush contaminants from the aquifer and decrease cleanup times.  Contaminants may be removed more quickly by groundwater advection rather than diffusion from layers of significantly lower hydraulic conductivity.

Sorbed contaminants can also be removed more quickly through vertical flow. Recirculation well technologies also have the advantage that they produce no net change in groundwater levels.

In many recirculating well systems, volatile compounds are removed by in-well air stripping or air sparging. In this type of recirculating well, a vertical zone of recirculation is created when contaminated groundwater is brought into the well from the aquifer with a submersible air-lift pump. Volatile contaminants are stripped in the well casing, and the contaminated air is treated above the ground surface, typically with vapor-phase activated carbon. Vapor-phase carbon generally has a much higher contaminant adsorption capacity than liquid-phase carbon. The clean air stream can either be released to the atmosphere or, in the case of a closed loop system, directed back into the well for the removal of additional VOCs.

Some recirculation wells use a submersible pump instead of an air lift pump to transport the influent to a stripping platform in the well vault. A potential variant of recirculation well technology would pump contaminated groundwater to the treatment unit to be treated using liquid-phase activated carbon while cycling within a larger recirculation well network. As with the air stripping and air sparging technologies, treated water would be reinjected at a different elevation in the same recirculation well to create an “upwelling” zone for circulation of groundwater. Recirculation wells will be included, as appropriate, in developing remedial alternatives for the A-Aquifer where they have already been implemented and shown to be successful for in situ lactate injection/recirculation.

Air sparging involves injecting air into the aquifer to physically strip or flush volatile contaminants as the air bubbles up through the groundwater and is captured by a vapor extraction system installed above the water table. In-well stripping (IWS) is an innovative variant of conventional air sparging in which a specially designed well is employed to physically remove VOCs and degradation products from groundwater via the process of air stripping. Although there are several configurations available, an air sparging-IWS well is typically made up of a large diameter well with two screen intervals vertically separated by a solid riser. A packer is set between the two screen intervals to separate them, and an airlift pumping system is established by injecting clean, compressed air through a drop tube and educator pipe that passes through a packer and is terminated within the lower screen interval. When the compressed air is injected into the drop tube, it creates a density driven air-lift pumping effect, which causes the groundwater in the lower portion of the well to rise up through the educator and discharge into the upper screened interval. The air-water contact that occurs within the educator pipe allows VOCs dissolved in groundwater to partition from the dissolved phase to the vapor phase.

The flow patterns established by the airlift pumping system carry water from the lower screen to the upper screen, and discharge treated groundwater into the upper aquifer zone. Radial flow occurs within the aquifer towards the lower screen, and away from the upper screen, with some component of flow vertically between the upper and lower aquifer zones. This flow pattern establishes a treatment and recirculation zone (or convection cell) around the well. The radius of influence of the process and the treatment zone is often estimated based on the amount of separation between the top of the lower screen and bottom of the upper screen. The size of the recirculation zone established in the aquifer from the IWS process is increased as the distance between the well screens is increased. In addition to VOC removal, the air sparging-IWS process will greatly increase dissolved oxygen (DO) concentrations in the surrounding treatment area, thus increasing the oxidation/reduction potential (ORP) potential of the groundwater system. This increase in ORP can stimulate aerobic biodegradation of amenable compounds (such as benzene, toluene or VC) and promote direct oxidation of susceptible compounds. However, as discussed in Section 3.2.2 above, CT and other COCs within these plumes primarily degrade under anaerobic, not aerobic conditions. In addition, air sparging-IWS does not destroy or degrade the VOCs, so that subsequent aboveground collection and treatment of vapor-phase VOCs with other technologies such as activated carbon would be required.

Air sparging-IWS technology could potentially be used at the leading edge of the plume for migration control and mass removal of VOCs present in the groundwater, and could also be used as groundwater circulation wells to mix or better distribute an injected reagent proposed for the in situ enhanced biodegradation process. This would be beneficial in deep, expansive, contaminant plumes where delivering substrate over a large area is difficult using conventional injection wells. However, this technology is not considered further at this time because it would also create an enhanced oxidized or aerobic zone within the aquifer under the influence of the groundwater circulation that is not considered favorable for biodegradation of CT within OUCTP. In addition, it would be difficult to implement for effective treatment of the low VOC concentrations in the groundwater within the relatively deep, high-flow aquifers and extensive plumes within OUCTP. Various configurations of recirculation and sparging wells will be considered further in the remedial design if determined to be necessary to enhance the effectiveness of other technologies considered.

### *Infiltration Galleries*

Infiltration galleries or trenches consist of a network of trenches with distribution pipes to carry water throughout a network. The system could be constructed with backhoe excavation, a geosynthetic drainage net, and slotted pipe. Installation with a trencher and flexible pipe is another option. The primary functional difference between infiltration trenches and reinjection wells is that infiltration trenches deliver water to the vadose zone, above the water table, and at shallower installation depths, are significantly less expensive than reinjection wells. Reinfiltration at much slower rates than reinjection wells buffers groundwater both from changes in the quantity and chemistry of reinjected water that is returned to the aquifer. In theory, trenches percolate water at a low enough velocity that sand grains would not be rearranged and therefore can function over long periods of time with little need for maintenance. However, infiltration galleries have been installed and operated at the former Fort Ord and have been prone to lose their capacity for infiltration and become clogged and inoperable. In addition, because infiltration galleries operate at low velocities, they may not be able to process the large volumes of groundwater (likely on the order of hundreds of gallons per minute) expected from the OUCTP GWET system, and are eliminated from further consideration at this time.

#### *Surface Water or Storm Drain Discharge*

Potential surface water discharge locations are not known to be of sufficient magnitude to be able to convey a significant portion of anticipated treatment plant effluent. On-site discharge of treated water to a surface water body from a CERCLA site would be required to meet the substantive, but not administrative, requirements of the National Pollutant Discharge Elimination System (NPDES). Off-site discharge would be required to meet both substantive and administrative requirements. Additionally, this option may not be acceptable to the public. Long pipelines would make this option moderately expensive. Because of a lack of other suitable locations in reasonable proximity of anticipated extraction and treatment locations, surface water body discharge will not be considered in developing remedial alternatives for the OUCTP plume.

#### *Discharge Locations*

The careful choice of a discharge location can help establish hydraulic control, minimize plume expansion, and reduce required treatment times. Discharge locations would be selected to minimize mounding and drawdown. The exact location of discharge points used during development of remedial alternatives will be determined by numeric groundwater modeling if the selected alternative includes GWET systems. Discharge locations will he reviewed and refined during the design process.

#### *Summary of Extraction and Recirculation Considerations*

Both groundwater extraction, reinjection, and recirculation wells will be considered in the development of remedial alternatives.

Advantages of GWET systems generally include reduced monitoring requirements; simpler design basis; larger capture zone per well; less geological sensitivity (requires less complex hydraulic modeling);

greater treatment efficiency (due to less recirculation and no reliance on air stripping); more flexibility; and greater experience.

Advantages of recirculation wells generally include inducing vertical flow; allowing for the discharge of treated water in the same well; does not require aboveground treatment of groundwater; and minimal water level changes.

## 3.4 Summary of Remedial Technology Screening

Based on the screening of technologies, the following technologies and process options were retained for the development of remedial alternatives:

***A-Aquifer Groundwater Remedial Unit***

- No Action with Monitored Natural Attenuation;
- In Situ Enhanced Biodegradation (e.g., injecting a carbon source such as lactate);
- In Situ Permeable Reactive Barrier; and
- Groundwater Extraction and Treatment (e.g., aboveground treatment using activated carbon adsorption or air stripping).

***Upper 180-Foot Aquifer Groundwater Remedial Unit***

- No Action with Monitored Natural Attenuation; and
- Groundwater Extraction and Treatment (via the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS).

***Lower 180-Foot Aquifer Groundwater Remedial Unit***

- No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (e.g., using activated carbon adsorption or air stripping).

The following section presents a general discussion of the technical feasibility of remediating groundwater below aquifer cleanup levels (MCLs; Table 2) for the remedial technologies retained for the development of alternatives. A more detailed discussion of the technical and economic feasibility of remediating groundwater below aquifer cleanup levels for each of the remedial alternatives is provided in the detailed analysis of alternatives based on the results of groundwater modeling and other site-specific considerations described in Sections 4.0 and 5.0.

## 3.5 Technical Feasibility of Achieving Aquifer Cleanup Levels

According to Section 2550.4, Chapter 15, Title 23 of the California Code of Regulations (CCR), "for a corrective action program, the regional board shall establish a concentration limit for a constituent of concern that is greater than the background value of that constituent only if the regional board finds that it is technologically or economically infeasible to achieve the background value for that constituent and that the constituent will not pose a substantial present or potential hazard to human health or the environment as long as the concentration limit greater than background is not exceeded.  In making this finding, the regional board shall consider the factors specified in subsection (d) of this section [below], the results of the engineering feasibility study submitted pursuant to subsection 2550.9(c) of this article, data submitted by the discharger pursuant to subsection 2550.9(d)(2) of this article to support the proposed concentration limit greater than background, public testimony on the proposal, and any additional data obtained during the evaluation monitoring program.

Subsection (d) indicates that in establishing a concentration limit greater than background for a constituent of concern, the regional board shall consider the following factors:

1. Potential adverse effects on groundwater quality and beneficial uses, considering:

    a. The physical and chemical characteristics of the waste in the waste management unit;

    b. The hydrogeological characteristics of the facility and surrounding land;

    c. The quantity of groundwater and the direction of groundwater flow;

    d. The proximity and withdrawal rates of groundwater users;

    e. The current and potential future uses of groundwater in the area;

    f. The existing quality of groundwater, including other sources of contamination or pollution and their cumulative impact on the groundwater quality;

    g. The potential for health risks caused by human exposure to waste constituents;

    h. The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and

i. The persistence and permanence of the potential adverse effects.

RWQCB Resolution 92-49 (92-49) contains similar requirements and considerations regarding the establishment of background or other aquifer cleanup levels, and states that “non-attainment” [of background conditions] zones may be established for two specific situations where water quality objectives cannot be achieved:

2. An approved cleanup program has been fully implemented and groundwater pollutant concentrations have reached asymptotic levels.

3. The site has limited water quality and environmental and human health risks, or cleanup to water quality objectives cannot be reasonably achieved.

In addition, 92-49 states that remediation technologies for reducing contamination must be fully evaluated and implemented to the extent reasonable, and residual contamination must be adequately contained and managed such that beneficial uses are not unreasonably affected outside the “non-attainment zone”.

Attainment of MCLs would protect beneficial uses of groundwater at OUCTP because there would be limited human health risks and no environmental risks. MCLs are risk-based levels and are already protective of human health. In addition, long term sampling and monitoring of chemical concentrations in these aquifers would be performed as part of remediation activities. Residual contamination would be addressed through post-remediation sampling: however, residual concentrations of chemicals below MCLs are not considered to pose significant detrimental effects to future beneficial uses of groundwater.

The following is a general discussion of the technical feasibility of achieving background levels in groundwater within OUCTP.

### Technical Feasibility Discussion

In *Alternatives for Groundwater Cleanup* (*National Research Council, 1994*) the Council stated that several studies have raised troubling questions about whether existing technologies are capable of solving groundwater contamination problems. These studies focused on "pump-and-treat" systems that are the most common technology for groundwater cleanup in the United States. The studies indicated that pump-and-treat systems may be unable to remove enough contamination to restore the groundwater to drinking water standards, or that removal may require a very long time, in some cases centuries.

In general, the aquifer characteristics within OUCTP and within the former Fort Ord (high-flow sandy soils) are amenable to pump and treat systems. However, the length of time required to achieve low part-per-billion cleanup levels within these aquifers, and a cost-benefit-analysis of treating large volumes of groundwater at low concentrations over long periods of time 30 years for the A-Aquifer based on the results of groundwater modeling (Scenario 2; Section 9.0 and Appendix F of the RI; Volume I) must be determined on a site-specific basis.

Since 1994 when the Council's report was published, the range of groundwater remediation approaches has evolved and increased dramatically. EPA's *Treatment Technologies for Site Cleanup: Annual Status Report (EPA, 2003)* documents the status and achievements, as of March 2003, of treatment technology applications at Superfund sites. The data in the report were gathered from Superfund Records of Decision (ROD) from fiscal year (FY) 1982 - 2002, Close-out Reports (COR) from FY 1983 - 2002, and project managers at Superfund remedial action sites. As described in Section 3.0, general trends in selection of groundwater remediation technologies indicate in situ technologies make up 42% of all source control treatments at Superfund remedial action sites. RODs selecting P&T alone have decreased from about 80% prior to FY 1993, to an average of 21% over the last 5 years (FY 1998 - 2002).

Because many in situ groundwater treatment remedies have been initiated in the last 5 years, performance data on the technical feasibility of achieving background or aquifer cleanup levels have yet to be assessed. However, many in situ enhanced biodegradation projects have demonstrated achievement of cleanup levels (*FRTR, 2000*).

The goals of the Council study were to review the performance of existing pump-and-treat systems, to assess whether there are scientific and technological limits to restoring contaminated groundwater, to consider the public health and economic consequences of contaminated groundwater, and to provide advice on whether changes in national groundwater policy are needed to reflect the limits of current technology.

The Council found that, at the majority of contaminated sites, the complex properties of the subsurface environment, and the complex behavior of contaminants in the subsurface interfere with the ability of conventional pump-and-treat systems to achieve drinking water standards for contaminated groundwater.

The Council's study concluded the following factors affect the feasibility of aquifer restoration.

- Physical Heterogeneity: The subsurface environment is highly variable in its composition. Very often, a subsurface formation is composed of layers of materials with vastly different properties, such as sand and gravel over rock, and even within a layer the composition may vary over distances as small as a few centimeters. Because fluids move preferentially through the pore spaces between the grains of sand and gravel, or through fractures in solid rock and because these openings are distributed nonuniformly, underground contaminant migration pathways are often extremely difficult to predict.

- Migration of Contaminants to Inaccessible Regions: Contaminants may migrate by molecular diffusion to regions inaccessible to the flowing groundwater. Such regions may be microscopic (for example, small pores within aggregated materials) or macroscopic (for example, clay layers). Once present within these regions, the contaminants can serve as long-term sources of pollution as they slowly diffuse back in the cleaner groundwater.

- Sorption of Contaminants to Subsurface Materials: Many common contaminants have a tendency to adhere to solid materials in the subsurface. These contaminants can remain underground for long periods of time and then be released when the contaminant concentration in the groundwater decreases.

- Difficulties in Characterizing the Subsurface: The subsurface cannot be viewed in its entirety, but is usually observed only through a finite number of drilled holes. Because of the highly heterogeneous nature of subsurface properties and the spatial variability of contaminant concentrations, observations from sampling points cannot be easily extrapolated, and thus knowledge of subsurface characteristics is inevitably incomplete.

While significant mass removal of contaminants can be achieved from affected aquifers, there has been little success in reducing concentrations to low target levels, including MCLs. This limited success is a result of a variety of factors including the fact that even high solubility contaminants adhere to soil particles and that groundwater pumping causes preferential flow in high permeability areas.

In addition, a 'rebound effect' is reported once systems are shut down. This effect is observed when low residual groundwater concentrations have been achieved during operation but tend to rise again after the system is turned off. One explanation is that saturated soils become dewatered and contaminants adhering to these soils are unaffected by continued system operation. Once the system is turned off, these soils become saturated again and residual contaminants are allowed to come into contact with the groundwater and recontaminate it.

Research shows that what is achievable, and what is being accomplished at most sites, is a reduction in environmental degradation and heath risk to a level that is acceptable.

### *Summary of Technical Feasibility Assessment*

Research indicates that the restoration of aquifers, using pump-and-treat technologies, has little success in reducing concentrations to low target levels, including MCLs. Based on this data, the Army believes adopting MCLs is an appropriate approach to setting cleanup goals and additional economic factors presented below support this. Sufficient performance data is not currently available to determine whether in situ remediation technologies are more successful at achieving MCLs.

For these reasons, and because MCLs are protective of human health and the environment, no significant benefit to human health or the environment is gained by remediation to levels below MCLs. Therefore, the Army believes that adopting MCLs as RAOs is an appropriate approach to establishing cleanup standards at OUCTP. This is supported by existing literature and performance data from a considerable number of sites; numerical model predictions of cleanup times; and risk assessment estimates which demonstrate that MCLs are protective of human health and the environment. Although the MCLs are above background, they represent the lowest groundwater concentrations that are technically and economically achievable; and MCLs comply with SWRCB Resolution 92-49 and other ARARs discussed in Section 2.2 and summarized in Table 1.

# 4.0 DEVELOPMENT AND DESCRIPTION OF REMEDIAL ALTERNATIVES

The remedial technologies retained for further consideration in Section 3.0 that represent a range of remedial approaches and response actions are assembled into remedial alternatives for detailed analysis using engineering judgment and site-specific considerations for each of the three groundwater remedial unit aquifers within OUCTP identified in Section 2.4. According to EPA RI/FS Guidance, taking no further action at the site should be one of the alternatives considered as a basis for comparison to other alternatives, and appropriate treatment and contaminant options should also be considered (*EPA, 1989b*).

The remedial alternatives were developed to provide a range of remedial approaches and response actions to meet the remedial action objectives (RAOs) described in Section 2.1, which include:

- Exposure Control—Prevent the potential exposure of child and adult residents to groundwater contaminants above ACLs; and
- To the extent practicable based on technical and economic feasibility, achieve:

  --Source Control—Prevent or minimize further degradation of groundwater at the site;

  --Plume Containment—Mitigate the potential for contaminants to continue to migrate offsite; and

  --Plume Remediation—Reduce contaminant concentrations in groundwater to below aquifer cleanup levels (ACLs).

As described in Section 2.3, in general, "exposure control" is achieved for OUCTP because groundwater from OUCTP is not currently supplied for domestic use, and the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999. Although there are currently no exposures to contaminants in groundwater within OUCTP, the Lower 180-Foot Aquifer has historically been and continues to be a significant source of potable water for the former Fort Ord and City of Marina area. The CT plume commingles with the Operable Unit 2 (OU2) TCE plume in the Lower 180-Foot Aquifer, and both contaminants appear to be migrating eastward toward the Marina Coast Water District (MCWD) municipal wells. To date, CT has not been detected in any of these drinking water wells.

Regardless of the remedial approaches and response actions considered in the development and description of remedial alternatives for OUCTP, it should be noted that a long-term groundwater monitoring program will be established and maintained as a component of all remedial alternatives developed for OUCTP in order to meet these RAOs that will establish “points of compliance” (i.e., groundwater monitoring wells within the plume and ‘background wells’ outside of the plume boundary) for assessment and management of groundwater contamination within OUCTP as part of the selected remedy established in the Record of Decision.

Following issuance of a final OUCTP RI/FS and Proposed Plan for public comment, a Record of Decision (ROD) will document the selected alternatives.  Once the ROD is issued, remedial design (if necessary) will begin.  During the remedial design phase, many of the uncertainties and generalities present in the FS will be resolved.

A review of the selected remedy(s) for OUCTP will be conducted within 5 years after implementation to determine whether the remedy(s) continues to be protective of human health and the environment and will be documented in a Five-Year Review report.  In addition, the Five-Year Review report will provide any newly identified site-related data or issues that are identified during the review, and identify recommendations to address them as appropriate.  A work plan would be developed for implementation of contingencies if the assumptions in the remedial design phase that follows the RI/FS and ROD are not met.

The remedial alternatives developed for each of the three groundwater remedial units identified in Section 2.4 are described in the following sections.

### *A-Aquifer Remedial Alternatives*

Four different remedial alternatives were developed for the A-Aquifer based on the aquifer characteristics described in Section 2.4; and the results of the previous treatability studies and the remedial technology screening presented in Section 3.0:

- No Action with Monitored Natural Attenuation;
- In Situ Enhanced Biodegradation;
- In Situ Permeable Reactive Barrier; and
- Groundwater Extraction and Treatment.

The alternatives were developed recognizing the following characteristics of the A-Aquifer plume as they relate to the remedial action objectives (RAOs):

- Exposure Control—There are currently no exposures to contaminants in groundwater, and the installation of new drinking water wells within this aquifer is already prohibited under County Ordinance.

- Source Control—There is no longer a source of chemicals to groundwater in the A-Aquifer and concentrations are generally decreasing over time.

- Plume Containment—The majority of the plume is contained within the boundaries of the former Fort Ord, but the downgradient ‘toe’ of the plume has migrated offsite into the City of Marina (Plate 2A). Groundwater in this portion of the aquifer flows at much higher rates than upgradient areas dues to the presence of a subsurface wave-cut terrace and would be difficult to contain using available technologies.

- Plume Remediation—Concentrations of COCs in groundwater are in the dissolved phase in the low parts per billion range, which can be difficult to remediate, especially within a high-flow aquifer and over such as large area. Over an extended period of time, natural attenuation of contaminants through transport, biological degradation, and dispersion would eventually reduce concentrations of contaminants in groundwater.

### *Upper 180-Foot Aquifer Remedial Alternatives*

Two different remedial alternatives were developed for the Upper 180-Foot Aquifer based on the aquifer characteristics described in Section 2.4 and the results of the remedial technology screening presented in Section 3.0:

- No Action with Monitored Natural Attenuation; and

- Groundwater Extraction and Treatment (Within the Existing Operable Unit 2 Groundwater Extraction and Treatment System [OU2 GWTS]).

The alternatives were developed recognizing the following characteristics of the Upper 180-Foot plume as they relate to the RAOs:

- Exposure Control—There are currently no exposures to contaminants in groundwater, and the installation of new drinking water wells within this aquifer is already prohibited under County Ordinance.

- Source Control—There is no longer a source of chemicals to groundwater in the uppermost A-Aquifer plume that has migrated/is migrating into the Upper 180-Foot Aquifer through two vertical conduits, and concentrations are generally decreasing over time. Once these vertical conduits are eliminated and/or the A-Aquifer is remediated or contained, the source of contamination in this aquifer would be controlled.

- Plume Containment—The plume is contained within the boundaries of the former Fort Ord and is located within the capture zone of the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS).

- Plume Remediation—Concentrations of COCs in groundwater are in the dissolved phase in the low parts per billion range, which can be difficult to remediate, especially within a high-flow, deep aquifer and over such as large area. Over an extended period of time, natural attenuation of contaminants through transport, biological degradation, and dispersion would eventually reduce concentrations of contaminants in groundwater.

### *Lower 180-Foot Aquifer Remedial Alternatives*

One remedial alternative was developed for the Lower 180-Foot Aquifer based on the aquifer characteristics described in Section 2.4 and the results of the remedial technology screening presented in Section 3.0:

- No Action with Monitored Natural Attenuation (and Wellhead Treatment Contingency).

The alternatives were developed recognizing the following characteristics of this plume as they relate to the RAOs:

- Exposure Control—There are currently no exposures to contaminants in groundwater; however, this aquifer has historically been and continues to be a significant source of potable water for the former Fort Ord and City of Marina area. The CT plume commingles with the OU2 TCE plume at this location and both contaminants appear to be migrating eastward toward MCWD municipal wells (Plate 4B). To date, CT has not been detected in any of these drinking water wells.

- Source Control—There is no longer a source of chemicals to groundwater in the uppermost A-Aquifer plume that has migrated/is migrating into the Upper 180-Foot Aquifer and then into the Lower 180-Foot Aquifer through two vertical conduits, and concentrations are generally decreasing over time. Once these vertical conduits are eliminated and/or the A-Aquifer and

Upper 180-Foot Aquifers are remediated or contained, the source of contamination in this aquifer would be controlled.

- Plume Containment—The southern Lower 180-Foot Aquifer OUCTP plume is contained within the boundaries of the former Fort Ord but is within approximately 3,000 feet of and migrating towards MCWD Well No. 29 (Plates 4A/4B). The majority of the northern Lower 180-Foot Aquifer OUCTP plume is contained within the boundaries of the former Fort Ord but a small portion of the western edge of the plume extends into and is migrating towards the City of Marina (Plates 4A/4B). Groundwater in the Lower 180-Foot Aquifer would be difficult to contain using available technologies.

- Plume Remediation—Concentrations of COCs in groundwater are in the dissolved phase in the low parts per billion range, which can be difficult to remediate, especially within a deep, high-flow aquifer. In addition, remediation of the plume via groundwater extraction and treatment and/or in situ technologies was eliminated from further consideration for the Lower 180-Foot Aquifer because (1) it would impact the hydrologic stability and/or geochemistry of this aquifer that is used for drinking water by the City of Marina; (2) the plume is limited in extent and has not impacted drinking water supply wells; and (3) its presence is due to vertical conduits identified in the RI (Volume I) that will be eliminated that are allowing dilute concentrations of VOCs in groundwater in the upper aquifers to travel into this aquifer. Over an extended period of time, natural attenuation of contaminants through transport, biological degradation, and dispersion would eventually reduce concentrations of contaminants in groundwater.

### *Development of Remedial Alternatives for OUCTP*

The development of the remedial alternatives focuses on the A-Aquifer remedial alternatives, because the A-Aquifer (1) contains the largest plume that is the source of contamination to the two lower aquifers; and (2) is the most accessible (shallowest) aquifer, making it more feasible to evaluate a number of different remedial approaches than for the deeper aquifers. Only one other alternative besides monitored natural attenuation was considered feasible for the Upper 180-Foot Aquifer; groundwater extraction and treatment within the existing OU2 GWTS. No other remedial alternatives were considered feasible for the Lower 180-Foot Aquifer except including a contingency for wellhead treatment in the monitored natural attenuation program in the event that the OUCTP plume in this aquifer migrates and COCs are detected in water supply wells (Plate 4B). Monitored natural attenuation could be applied simultaneously for all three aquifers, and therefore was developed as one comprehensive alternative for all three aquifers. In situ enhanced biodegradation, on the other hand, could only be applied in the A-Aquifer, but could be combined with groundwater extraction and treatment [GWET] in the Upper 180-Foot Aquifer and monitored natural attenuation in the Lower 180-Foot Aquifer, etc.

For the purposes of this FS, remedial alternatives were assembled to provide a logical and comprehensive approach for remediation of all three aquifers based on engineering judgment and the results of the remedial technology screening presented in Section 3.0. The following assumptions associated with development of the alternatives will be further refined and reevaluated in the remedial design phase, during which many of the uncertainties and generalities present in this FS will be resolved, including the technical and economic feasibility of implementing the range of options considered herein:

- Alternate Remedial Technology Combinations and Cleanup Approaches (All Aquifers)—A number of alternate combinations of remedial technologies could be developed for remediation of each aquifer (e.g., extraction and treatment of groundwater from the downgradient portion of the plume and injection of nano-scale iron in discrete upgradient locations); various contingencies could be triggered for any of the point of compliance monitoring wells within any of the aquifers that contain COCs above ACLs; and non-attainment zones could be established for portions of the plumes that would be technically or economically infeasible to remediate below ACLs using a phased approach over time depending on the plume status. However, for the purposes of this evaluation, the most effective remedial technologies were assembled into stand-alone full-scale remedial alternatives for each plume and were evaluated in terms of their ability to achieve ACLs throughout the entire plume.

- Monitored Natural Attenuation (All Aquifers)—Wellhead treatment could be included as a contingency and be triggered for any of the point of compliance monitoring wells within any of the aquifers that contain COCs above ACLs. However, for the purposes of this evaluation, this contingency is only included in the evaluation of alternatives for the Lower 180-Foot Aquifer that is a current potable source of drinking water.

- In Situ Enhanced Biodegradation (A-Aquifer)—Injection of a number of different carbon sources could potentially be effective in enhancing the anaerobic biodegradation of CT in situ (e.g., HRC®, molasses, lactate). However, for the purposes of this evaluation, it is assumed the carbon source would be lactate because it was demonstrated to be effective in a site-specific pilot biotreatability study (Section 3.2.2).

- In Situ Permeable Reactive Barrier (A-Aquifer)—Injection of a number of different iron materials could potentially be implemented to enhance the degradation of CT in situ (e.g., zero-valent iron, nano-scale iron, nickel-plates iron, iron filings), in more than one location within the plume. However, for the purposes of this evaluation, it is assumed the iron material would be ZVI because it has proven effectiveness at the largest number of similar sites, and it would be implemented within a single downgradient (migration control) location. However, if it is determined the PRB is not achieving adequate control and remediation of the plume, nano-scale iron could be injected at discrete locations throughout the plume (in lieu of installing additional barriers).

- Groundwater Extraction and Treatment (A-Aquifer)—Extraction wells (EWs) could be located based on a number of different configurations and considerations, such as in onsite primary source areas; the toe or leading edge of the plume; offsite downgradient locations where the plume has migrated; point-of compliance locations. However, for the purposes of this evaluation, it is assumed the EWs would be installed within the area of highest CT concentrations that are onsite and accessible in order to maximize source removal. In addition, aboveground treatment of extracted groundwater could potentially be achieved using a number of different technologies (e.g., activated carbon adsorption, air stripping, aeration, bioslurry) and configurations (e.g., modular wellhead treatment at individual wells, a single large-scale central processing treatment system). However, for the purposes of this evaluation, it is assumed either activated carbon or air stripping would be implemented at a central treatment system location because these technologies have proven effectiveness at many similar sites, and the equipment and infrastructure required to construct a single treatment system location are more readily available and typically less costly than individual wellhead treatment configurations.

The remedial alternatives are described in the following sections as follows:

- Remedial Alternative 1—No Action With Monitored Natural Attenuation (All Aquifers).

- Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

- Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

- Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation with Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

## 4.1 Remedial Alternative 1—No Action With Monitored Natural Attenuation (All Aquifers)

The no action alternative is provided, as required under CERCLA and the NCP as a baseline for comparison to the other proposed alternatives. This alternative assumes that over an extended period of time, natural attenuation of contaminants through transport, biological degradation, and dispersion would eventually reduce concentrations of contaminants in groundwater. If no action were taken to actively remediate OUCTP, the progress of natural attenuation within the three aquifers would need to be actively monitored and reassessed on a regular basis in order to meet the RAOs for these plumes.

The monitored natural attenuation (MNA) program would establish “points of compliance” (i.e., groundwater monitoring wells within the plume and ‘background wells’ outside of the three different aquifer plume boundaries) that would be used for assessment of how well the selected remedy is achieving the RAOs over time (e.g., verifying chemical concentrations in groundwater and offsite plume migration are not increasing in a statistically significant manner). No additional institutional controls such as deed restrictions would be included in this alternative to prevent use of groundwater; the installation of new drinking water wells at the former Fort Ord is already prohibited under Monterey County Ordinance No. 04011, dated April 1999.

For the purposes of analysis and costing in this FS, this alternative assumes:

- The plume(s) would naturally attenuate over a period of approximately 30 years to meet RAOs.
- Chemical concentrations in groundwater and offsite plume migration would not increase in a statistically significant manner.
- The two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated as follows (Plate 4B): (a) Monitoring Well MW-B-13-A will be destroyed (grouted and sealed); and (b) the Mini-Storage well will be destroyed (grouted and sealed), or if it is determined that it could be converted into an extraction well (EW) that would provide additional containment of the plume, groundwater extracted from this well would be treated at the well-head

(via activated carbon or air stripping as described in Section 3.3.2) and tied into the existing piping conveyance system that transfers the treated water into the existing water supply system.

- Up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer, and would be monitored for a period of 30 years.
- A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells (Plate 4B).

Existing and newly installed groundwater wells within these aquifers would be monitored under the protocols of the existing monitoring program described in the RI (Volume I) using a phased approach over a 30-year period as follows:

- Years 1—5: Quarterly monitoring and reporting (every 3 months).
- Years 6—10: Semi-annual monitoring and reporting (every 6 months).
- Years 11—30: Annual monitoring and reporting (every 12 months).

The MNA monitoring program would include collection, analysis, and reporting of groundwater sampling data from the existing monitoring wells and up to 30 additional MNA ‘point of compliance’ monitoring wells using the protocols described in Section 3.7 of the RI (Volume I) as follows:

- Groundwater samples would be collected and analyzed for VOCs (EPA Test Method 8260) and natural attenuation parameters including ferric and ferrous iron, sulfate, nitrate and nitrite, and dissolved gasses.
- Groundwater samples would be analyzed and measured in the field for titrated alkalinity, Oxidation Reduction Potential (ORP) and Dissolved Oxygen (DO).
- Concentrations of CT and its daughter product chloroform would be evaluated and molar ratios would be calculated to assess the extent to which biological degradation of CT within the aquifer is occurring.

- Capital costs associated with planning and installing up to 30 additional monitoring wells to ‘bound’ the plumes are estimated at approximately $558,000. Operations and maintenance costs for 30 years of monitoring and reporting are estimated at approximately $2.19 million, for a total estimated 30-year net present value (NPV) cost of $2.75 million. Costing assumptions and estimates for this alternative are presented in Table A1 of Appendix A. Costs associated with contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would be estimated during the remedial design phase for implementation of the selected alternative.

## 4.2 Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation With Wellhead Treatment Contingency (Lower 180-Foot Aquifer)

This alternative presents (1) an in situ remediation scenario for treatment and migration control of the A-Aquifer groundwater plume via a large network of enhanced biodegradation injection points throughout the entire plume (Plate 5); (2) groundwater extraction and treatment and migration control of the Upper 180-Foot Aquifer via extraction wells (Plate 8) and treatment within the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS); and (3) monitored natural attenuation with wellhead treatment contingency of the Lower 180-Foot Aquifer if COCs are detected in water supply wells (Plate 4B).

The groundwater extraction and treatment alternative for the Upper 180-Foot Aquifer is the same for Remedial Alternatives 2-4, and is described in detail under this Remedial Alternative 2. The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

### *A-Aquifer*

The effectiveness of in situ enhanced biodegradation via injection and recirculation of lactate in reducing CT concentrations in the A-Aquifer has been demonstrated in site-specific bench-scale and pilot treatability studies as described in Section 3.9 of the RI (Volume I) and summarized in Section 3.2.2. The groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the A-Aquifer CT-plume to below aquifer cleanup levels (ACLs) within a time period of approximately 15 years (Scenario 3; Section 9.0 and Appendix F of the RI; Volume I). Creating large anaerobic zones would have a substantial impact on the subsurface environment and greatly alter local geochemical balances. Full scale applications of in situ enhanced biodegradation systems have experienced numerous operational difficulties, such as aquifer fouling. This potential will be further evaluated during the remedial design phase if this technology is selected for implementation; reintroduction of oxygen downgradient of the treatment area to restore the aerobic balance of the aquifer could be considered if potential impacts are identified (e.g., using air sparging/recirculation wells).

As shown on Plate 5, which illustrates the lactate injection locations and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 15 years of treatment (Year 15), this alternative would be effective at reducing COCs below ACLs, and would be implemented as follows:

- A line of 10 treatment cells that each span the width of the plume (aligned perpendicular to groundwater flow) shown on Plate 5.

- Each of the 10 treatment cells would consist of a series of lactate injection points located every 40 feet across the cell (10 to 30 injection points per treatment cell depending on the varying width of the plume, each with a radius of influence of 20 feet).

- The majority of injection points would be installed to a depth of approximately 100 feet bgs as permanent 4-inch diameter recirculation wells (as were demonstrated to be effective in the pilot biotreatability study) that would aid in the distribution of lactate throughout the aquifer and could be reinjected with lactate as often needed to maintain favorable biodegradation rates within the aquifer (approximately every 2.5 years). Advantages of recirculation wells include inducing vertical flow; allowing for the discharge of treated water in the same well; not requiring construction and maintenance of an aboveground treatment unit; and minimal water level changes as the groundwater is not removed from the aquifer.

- The remainder of injection points located in the portion of the plume that has migrated offsite into the City of Marina (referred to as the downgradient ‘toe of the plume’) would be installed using direct-push injection techniques due to constraints on installing and constructing permanent wells and an aboveground treatment system within developed areas, and would have to be reinjected as often needed to maintain favorable biodegradation rates within the aquifer (approximately every 2.5 years).

- Approximately 250 gallons of a 60% sodium lactate solution would be injected at each injection point every 2.5 years until concentrations of COCs are at or below ACLs or are asymptotic (no longer declining) near ACLs (approximately 15 years, or a total of 6 injection events).

- A total of approximately 65,750 gallons of 60% sodium lactate solution would need to be applied at a total 263 A-Aquifer injection points during each injection event.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated as follows: (a) Monitoring Well MW-B-13-A will be destroyed (grouted and sealed); and (b) the Mini-Storage well will be destroyed (grouted and sealed), or if it is determined that it could be converted into an extraction well (EW) that would provide additional containment of the plume, groundwater extracted from this well would be treated at the well-head (via activated carbon or air stripping as described in Section 3.3.2) and tied into the existing piping conveyance system that transfers the treated water into the existing water supply system.

- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells.

- Treatment system monitoring would be conducted as described under Alternative 1 for VOCs and natural attenuation parameters throughout the duration of treatment (15 years) and an additional 5 years of follow-up monitoring to assess the potential for concentrations of COCs to ‘rebound’ after treatment is discontinued, for a total duration of 20 years. Groundwater Monitoring of the OUCTP monitoring wells (MWs) would be conducted for a period of 30 years.

- Natural attenuation indicator data described under Alternative 1 would be analyzed to gauge the level of enhanced biodegradation within the aquifer and determine the need for and estimate the time between lactate reinjection events.

- Capital costs associated with installing the lactate injection and recirculation treatment system and additional monitoring wells, and conducting the first lactate injection event are estimated at approximately $4.63 million. Treatment system operations and maintenance costs for 15 years and 20 years of monitoring and reporting are estimated at approximately $4.90 million, for a total estimated 20-year NPV cost of $9.54 million. Costing assumptions and estimates for this alternative are presented in Table A2 of Appendix A.

### *Upper 180-Foot Aquifer*

This alternative presents a containment approach that includes a pumping scenario for migration control of the groundwater plume with aboveground treatment and reinjection of treated water back into the aquifer. This alternative assumes the newly installed groundwater extraction well EW-OU2-07-180 that is a component of the optimized Operable Unit 2 Groundwater Treatment System (OU2 GWTS) would be pumped at a total flow rate of approximately 150 gallons per minute (gpm) for capture of the majority of the Upper 180-Foot Aquifer plume as shown on Plate 8. The extracted water would be collected and treated at the existing aboveground central process and control area of the OU2 GWTS.

As shown on Plate 8, which illustrates the well locations, particle tracking streamlines, and concentrations of COCs within the plume from the most recent groundwater monitoring data (September 2004) that were used in the simulation, the results of the groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the majority of the Upper 180-Foot Aquifer plume to below aquifer cleanup levels (ACLs) within a time period of approximately 30 years (Scenario 2; Section 9.0 and Appendix F of the RI; Volume I) as follows:

- The newly installed groundwater extraction well EW-OU2-07-180 that is a component of the optimized Operable Unit 2 Groundwater Treatment System (OU2 GWTS; *Shaw, 2005*) would be pumped at a total flow rate of approximately 150 gpm. Groundwater modeling indicated this well would also provide capture of the commingled CT plume associated with OU2 located near the area where these two plumes merge in the Upper 180-Foot Aquifer prior to entering the Lower 180-Foot Aquifer (Plates 3 and 8).

- Optimization procedures would need to be implemented within the OU2 GWTS to incorporate the additional flow of 150 gpm into the current treatment system, which has an approximate capacity limitation of 1,000 gpm.

- The extracted groundwater would require treatment within the existing OU2 GWTS to meet reinjection standards (discharge limits) for the COCs listed in Table 2, which are anticipated to be MCLs or detection limits using EPA Test Method 8260.

- A pipeline between the EW and the OU2 GWETS would need to be constructed to allow transfer of the extracted groundwater to the treatment plant.

- Treated effluent would be reinjected back into the aquifer through the reinjection wells associated with the existing OU2 GWTS.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot Aquifer will be eliminated, and groundwater monitoring of existing and new wells would be conducted as described under Alternative 1 for VOCs for a period of 30 years to assess the potential for concentrations of COCs to 'rebound' due to declining effectiveness of the GWET system and to monitor the nature and extent of the plumes.

- Implementation of this alternative if it is selected would be conducted as part of optimization of the existing OU2 GWET system during the remedial design phase. Costs associated with installing additional extraction wells, piping conveyance to tie these wells into the existing OU2 GWETS, and additional treatment capacity to treat groundwater extracted from this aquifer would be estimated during the remedial design associated with the optimization of the OU2 GWTS.

## 4.3 Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation With Wellhead Treatment Contingency (Lower 180-Foot Aquifer)

This alternative presents (1) an in situ remediation and containment approach that includes installation of an in situ permeable reactive barrier (PRB) near the downgradient plume boundary for offsite migration control of the A-Aquifer plume (Plate 6); (2) groundwater extraction and treatment and migration control of the Upper 180-Foot Aquifer via extraction wells (Plate 8) and treatment within the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS); and (3) monitored natural attenuation with wellhead treatment contingency of the Lower 180-Foot Aquifer if COCs are detected in water supply wells.

The groundwater extraction and treatment alternative for the Upper 180-Foot Aquifer is the same for Remedial Alternatives 2-4, and is described in detail under Remedial Alternative 2. The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

As shown on Plate 6, which illustrates the PRB location and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 30 years of treatment

(Year 30), this alternative would be effective in the long term at reducing COCs below ACLs, and would be implemented as follows.

***A-Aquifer***

The in situ permeable reactive barrier (PRB) would be installed near the downgradient plume boundary for offsite migration control of the A-Aquifer plume as shown on Plate 6, which illustrates the PRB location and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 30 years of treatment (Year 30), which is the cut-off for remedial alternative evaluations, cost estimating, and comparisons under EPA's RI/FS Guidance (*EPA*, *1989b*). However, the results of the groundwater modeling simulation of this alternative indicated it would only be effective in remediating concentrations of COCs in the A-Aquifer plume to below aquifer cleanup levels (ACLs) within a time period of approximately 50 years in the area downgradient of the PRB, and typical PRB effectiveness timeframes are on the order of 20 years. Therefore, although the PRB may only be effective for a period of 20 years, and was not predicted to be able to achieve ACLs for up to 50 years, for the purposes of this evaluation, it was assumed to operate for a period of 30 years as specified under EPA's RI/FS Guidance (*EPA*, *1989b*). Nano-scale iron could also be injected in a slurry form in isolated locations for targeted source removal in other portions of the plume to supplement the PRB, and would be further evaluated during the remedial design phase if this alternative is selected for implementation as follows:

- A pilot study would be conducted within a portion of the A-Aquifer plume to determine the site-specific effectiveness of this technology and (1) further refine design parameters such as iron consumption rates and effective flow-through thickness and residence times; (2) select a preferred injection technique; and (3) evaluate hydrogeologic data to analyze potential impacts of groundwater chemistry on the long-term performance of the PRB.

- If the results of the pilot study indicate a PRB would be effective, a full-scale PRB would be installed between monitoring wells MW-BW-43-A and MW-BW-44-A, east (upgradient) of the higher hydraulic conductivity zone coincident with the wave-cut terrace in the underlying FO-SVA (Plates 2A/2B and 6). This location was chosen for three reasons: (1) property within the former Fort Ord footprint is accessible for significant remedial activities associated with a PRB, (2) a roadway along the perimeter of the biological reserve provides an area where a PRB may be installed without disturbing the reserve, and (3) the depth to the FO-SVA is shallowest in this area (ranging from 35 to 65 feet), reducing the cost of installing a PRB relative to areas east or west of this location.

- The PRB would comprise three cells, fully penetrating the A-Aquifer, with a total length across the width of the plume (perpendicular to groundwater flow) of approximately 1,143 feet and a flow-through thickness of approximately 1 foot.

- The PRB cells would be constructed by installing zero valent iron (ZVI) or similar materials capable of long-lasting degradation of COCs. Laboratory bench-scale studies would be required to determine site-specific contaminant degradation rates and required residence times in ZVI or similar materials, and to evaluate the impact of groundwater chemistry on the long-term performance of the PRB.

- Although long term performance data is not available for PRBs, the typical effective remediation lifespan of a PRB is estimated at approximately 20-30 years. Groundwater modeling simulation results indicate that a PRB would take up to 50 years or more to passively remediate the A-Aquifer plume. Therefore, the PRB may have to be reinstalled should its ability to remediate the A-Aquifer decline over time. However, for the purposes of evaluating and costing this alternative, it is assumed to remediate the plume within a period of 30 years, which is the maximum period used for costing alternatives under EPA's RI/FS Guidance (*EPA, 1988*).

- The PRB cells would be installed throughout the vertical depth of the A-Aquifer and be keyed into the silty clay aquitard (FO-SVA) that separated it from the Upper 180-Foot Aquifer to prevent the potential for underflow of contaminated groundwater beneath the PRB.

- Groundwater modeling indicated the PRB would remediate the majority of the CT plume upgradient of the PRB within 50 years, with only a small portion (located between the PRB and MW-BW-31-A) of the plume remaining at concentrations ranging from 0.5 to 1.5 ug/L. However, groundwater downgradient of the PRB would remain contaminated at concentrations ranging between 0.5 and 5 ug/L due either to the continued migration of CT already present downgradient of the PRB or from residual CT emanating from the PRB. Therefore, it is anticipated that designation of a Non-Containment Zone (Section 2.2 and Table 1) may be required for this area since it would contain COCs above ACLs for an undetermined period of time.

- A disadvantage to installing a PRB in this area is that CT has been detected at concentrations exceeding the state MCL (0.50 ug/L) in monitoring wells downgradient of this area. In particular, the detection of 4.8 ug/L of CT at MW-BW-49-A in December 2004 indicates that a relatively significant amount of mass has already migrated into the high conductivity area of the A-Aquifer.

The installation of a PRB further west (downgradient) of this monitoring well is not practicable due to dense residential and commercial development. Therefore, the PRB would allow a portion of the CT plume to continue migrating westward where it would be naturally attenuated over time, primarily by advective and dispersive processes.

- Up to 10 observation wells would be installed along the upgradient (5 wells) and downgradient (5 wells) lengths of the PRB to monitor concentrations of COCs and groundwater chemistry and assess the effectiveness of the barrier in remediating the plume.
- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated as follows: (a) Monitoring Well MW-B-13-A will be destroyed (grouted and sealed); and (b) the Mini-Storage well will be destroyed (grouted and sealed), or if it is determined that it could be converted into an extraction well (EW) that would provide additional containment of the plume, groundwater extracted from this well would be treated at the well-head (via activated carbon or air stripping as described in Section 3.3.2) and tied into the existing piping conveyance system that transfers the treated water into the existing water supply system.
- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells.
- Groundwater monitoring would be conducted as described under Alternative 1 for VOCs and natural attenuation parameters throughout the duration of treatment (15 years) and an additional 5 years of follow-up monitoring to assess the potential for concentrations of COCs to ‘rebound’ after treatment is discontinued, for a total duration of 20 years.
- Natural attenuation indicator data described under Alternative 1 would be analyzed to gauge the level of enhanced biodegradation within the aquifer and determine the need for reinjection of ZVI.

- Capital costs associated with installing the PRB and additional monitoring wells are estimated at approximately $8.73 million. Operations and maintenance and monitoring and reporting costs for 30 years are estimated at approximately $4.42 million, for a total estimated 30-year NPV cost of $13.15 million. Costing assumptions and estimates for this alternative are presented in Table A3 of Appendix A.

## 4.4 Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Within OU2 GWTS (Upper 180-Foot Aquifer); Monitored Natural Attenuation With Wellhead Treatment Contingency (Lower 180-Foot Aquifer)

This alternative presents a containment approach that includes a pumping scenario for migration control of the groundwater plume with aboveground treatment and reinjection of treated water back into the aquifer. The components of this alternative for the A-Aquifer are described below.

The groundwater extraction and treatment alternative for the Upper 180-Foot Aquifer is the same for Remedial Alternatives 2-4, and is described in detail under Remedial Alternative 2. The monitored natural attenuation alternative with wellhead treatment contingency is the same for all remedial alternatives for the Lower 180-Foot Aquifer, and is described in detail under Remedial Alternative 1.

As shown on Plate 8, which illustrates the extraction well locations and concentrations of COCs within the plume used in the simulation after the first year of treatment (Year 1) and at the end of 30 years of treatment (Year 30), this alternative would be effective at reducing COCs below ACLs, and would be implemented as follows.

***A-Aquifer***

For the A-Aquifer, this alternative assumes five groundwater extraction wells pumping at a total flow rate of approximately 150 gallons per minute (gpm) for capture of the majority of the A-Aquifer plume within 30 years as shown on Plate 7. The extracted water would be collected at an aboveground central process and control area.

As shown on Plate 7, which illustrates the well locations, particle tracking streamlines, and concentrations of COCs within the plume from the most recent groundwater monitoring data (September 2004) that were used in the simulation, the results of the groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the majority of the A-Aquifer plume to below aquifer cleanup levels (ACLs) within a time period of approximately 30 years (Scenario 2; Section 9.0 and Appendix F of the RI; Volume I) as follows:

- Five extraction wells would be installed within the A-Aquifer CT plume footprint to provide capture of the majority of the plume that lies upgradient of proposed extraction well (EW) EW-OUCTP-01.

- The extraction wells would pump at 50 gallons per minute (gpm), 40 gpm, 30 gpm, 35 gpm, and 10 gpm from EW-OUCTP-01-A, EW-OUCTP-02-A, EW-OUCTP-03A, EW-OUCTP-04A, and EW-OUCTP-05-A, respectively.

- The portion of the plume that lies downgradient of EW-OUCTP-01 would not be technically feasible to capture, because based on the groundwater modeling simulation, any increase in the estimated pumping rate above 50 gpm would dry up the well.  Concentrations of CT in the downgradient (uncaptured) portion of the plume are estimated to range from between 0.5 to 5 ug/L based on current plume conditions (the aquifer cleanup level for CT is 0.5 ug/L).

- Although concentrations of COCs in the downgradient portion of the plume are expected to decline over time (through advective and dispersive natural attenuation processes and reduction of the source of contamination as the upgradient plume is captured, treated, and reinjected), it is anticipated that designation of a Non-Containment Zone (Section 2.2 and Table 1) may be required for this area since it would contain COCs above ACLs for an undetermined period of time.

- The extracted groundwater would require treatment to meet reinjection standards (discharge limits) for the COCs listed in Table 2, which are anticipated to be MCLs or detection limits using EPA Test Method 8260.

- Given the low anticipated influent concentrations and the anticipated discharge requirements, treatment of extracted groundwater to below MCLs could be achieved by processing the water through activated carbon adsorption vessels or a low-flow air stripper.  Both of these treatment options are included in the analysis of this alternative for comparison purposes, and because they are proven and effective methods for treating the extracted groundwater; have similar capital and operations and maintenance costs; and would be readily available for installation at a central processing and treatment location.  A preferred treatment method would be identified in the remedial design phase if this alternative is selected for implementation.

- Based on preliminary vendor quotes (1) the activated carbon adsorption treatment system would consist of two 2,000-pound carbon vessels attached in series that would require changeout (replacement of spent carbon) and offsite regeneration approximately once a month, and (2) the air stripper treatment system would consist of a single stacked unit constructed of four air stripping trays that could be cleaned and maintained onsite. For both options, influent and effluent treatment system sampling for VOCs (EPA Test Method 8260) would be performed as part of routine operations and maintenance.

- A piping conveyance system would be installed between the five EWs and the GWETS to allow transfer of the extracted groundwater to a centrally located treatment plant north of Reservation Road (Plate 7). Piping connecting two of the EWs located south of Reservation Road to the treatment plant would need to be installed using horizontal drilling techniques beneath the road.

- Treated effluent would be reinjected back into the aquifer through reinjection wells located within the footprint of the plume to augment flow to the extraction wells, placed approximately along the plume axis.

- As described under Alternative 1, the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated as follows: (a) Monitoring Well MW-B-13-A will be destroyed (grouted and sealed); and (b) the Mini-Storage well will be destroyed (grouted and sealed), or if it is determined that it could be converted into an extraction well (EW) that would provide additional containment of the plume, groundwater extracted from this well would be treated at the well-head (via activated carbon or air stripping as described in Section 3.3.2) and tied into the existing piping conveyance system that transfers the treated water into the existing water supply system.

- As described under Alternative 1, up to 30 additional “point of compliance” monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells.

- Groundwater monitoring of existing and new wells would be conducted as described under Alternative 1 for VOCs for a period of 30 years to assess the potential for concentrations of COCs to 'rebound' due to declining effectiveness of the GWET system and to monitor the nature and extent of the plumes.

- Capital costs associated with installing the extraction, treatment, and reinjection system and additional monitoring wells are estimated to range from approximately $2.38 to $2.45 million, depending on whether activated carbon or air stripping treatment is selected for implementation during the remedial design phase. Treatment system operations and maintenance costs for 30 years of monitoring and reporting range from approximately $11.06 to $17.46 million depending on the treatment method, for a total 30-year NPV estimated cost ranging from $13.44 to $19.92 million. Costing assumptions and estimates for this alternative are presented in Tables A4 and A5 of Appendix A for the activated carbon and air stripping treatment options, respectively.

# 5.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the evaluation and comparison of remedial alternatives described in Section 4.0. Table 4 summarizes the evaluation and comparison of alternatives that is conducted in accordance with the Guidance for Conducting Remedial Investigations/Feasibility Studies Under CERCLA (*EPA, 1988*) using the following nine criteria.

***Threshold Criteria***

1. Overall Protection of Human Health and the Environment – An alternative must eliminate, reduce, or control threats to public health and the environment through treatment or institutional controls. Each remedial alternative is evaluated in terms of the extent of protection of human health and the environment and the residual risk associated with implementation of the alternative. The manner in which the contaminants are managed under each alternative is considered.

2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) – The alternative must meet federal and State environmental statutes, regulations, and other requirements that pertain to the site or area unless a waiver is justified. The ability of each alternative to meet ARARs and other guidance identified in Section 2.2 and summarized in Table 1 is assessed.

***Balancing Criteria***

1. Short-Term Effectiveness – Considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation. The effects of each alternative during the construction, implementation, and operation phases is assessed. Factors considered included the protection of the community and workers during remedial operations, the time required to implement the alternative and to achieve the remedial goals, and the potential adverse environmental impacts that may result.

2. Long-Term Effectiveness and Permanence – Considers the ability of an alternative to maintain protection of human health and the environment over time. Each alternative is evaluated with respect to the risk that would remain at the site after the alternative has been implemented and the remedial action objectives (RAOs) have been satisfied. The magnitude of the risk is evaluated as well as the adequacy and reliability of long-term management controls required by the alternative.

3. Reduction of Toxicity, Mobility, or Volume Through Treatment – Evaluates the alternative's use of treatment (for which there is a statutory preference) to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present. Under CERCLA, preference is given to remedial technologies that significantly reduce the toxicity, mobility, or volume of contaminants. This evaluation focuses on the following factors for a particular remedial alternative:

    - The treatment process the remedy will employ and the materials treated;
    - The amount of hazardous materials that will be treated or destroyed;
    - The degree of expected toxicity, mobility, or volume reduction as compared to conditions prior to the remedial action;
    - The degree to which total destruction is achieved;
    - The type and quantity of treatment residuals that will remain following treatment; and
    - The degree to which the alternative addresses the principal risk.

4. Implementability – Considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services. Technical feasibility considerations include the availability of services, necessary equipment, and skilled workers to implement a particular alternative. Administrative feasibility includes obtaining necessary permits and regulatory approvals for implementation of the alternative. The three major areas of focus in assessing the implementability of a remedial action alternative are:

    - Technical Feasibility – The ability to construct a treatment system, the reliability of the technology, and the ability to monitor the effectiveness of the remedy.
    - Administrative Feasibility – The effort and resources required to obtain approvals from responsible agencies.
    - Availability of Services and Materials – The availability of contractors with the equipment and knowledge to implement the technologies under the remedial alternatives.

5. Cost – Remedial alternative cost estimates are prepared using EPA guidance manuals, other technical resource documents, contractor quotes, and experience on this site and on other projects of similar scope. Both capital costs and operation and maintenance (O&M) costs are developed at a conceptual level for each remedial action alternative. Capital costs include up-front costs to implement the remedial alternative such as contractors' mobilization and demobilization, complying with the substantive requirements of permits, engineering, remedial equipment purchase and installation, sampling and analysis during start-up, and site restoration. O&M costs include ongoing costs such as operational site inspections, utilities, chemicals, routine maintenance and repairs, and periodic sampling and analysis.

Capital and operations and O&M costs are estimated for each alternative based on quotes for labor, materials, and equipment necessary to implement the alternative. For annual O&M costs, the net present value (NPV) is calculated over the expected period of years it will take to implement the alternative based on real discount rates (similar to interest rates) that vary according to the period of performance for federal projects. For those alternatives whose life-cycle is indeterminate or exceeds 30 years, for the purposes of evaluating and comparing alternatives as specified in EPA's RI/FS Guidance (*EPA, 1988*), a period of 30 years is used for estimating long-term O&M costs.

USACE/EPA provide guidelines for estimating remedial alternative costs in OSWER Directive 9355.0-75 (January 2005; updated yearly), Office of Management and Budget (OMB), Executive Office of the President, Appendix C. The guidelines for federal projects are applied to cost estimates for the alternatives. These cost estimates are for planning purposes and are intended to have an accuracy of +50 percent/-30 percent. Assumptions used to develop costs for each alternative are listed in Appendix A, Tables A1—A5.

***Modifying Criteria***

1. State (Regulatory) Acceptance – Evaluates technical and administrative issues and concerns that the State, federal, and other regulatory agencies may have regarding each alternative. Regulatory acceptance will be addressed in the Proposed Plan and Record of Decision (ROD) once comments on the FS report have been received.

2. Community Acceptance – Evaluates issues and concerns that the public may have regarding each alternative. Each remedial alternative is evaluated in terms of available public input and the anticipated public reaction to the alternative. Community acceptance will be addressed in the ROD once comments on the FS report and Proposed Plan have been received (*EPA, 1988*).

The remedial alternatives for groundwater in the three OUCTP aquifers are evaluated and compared below based on their ability to achieve the evaluation criteria.

Four different remedial alternatives were developed based on the results of previous treatability studies and the remedial technology screening as described in Section 4.0:

- Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers).
- Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer).
- Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer).
- Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer).

These alternatives are evaluated and compared in the following sections that correspond with each of the nine EPA evaluation criteria described above. A summary of the evaluation and comparison is presented in Table 4.

## 5.1 Overall Protection of Human Health and the Environment

Each of the alternatives would offer varying levels of protection of human health, and all alternatives are assumed to be protective of the environment because no ecological receptors have been identified as potentially being exposed to groundwater containing COCs within these aquifers.

Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers): This alternative would not provide significant protection of human health and the environment because it takes no action to control potential exposures or sources of contamination other than to (1) monitor the status of the plumes assuming the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers would be eliminated, and (2) implement a contingency for wellhead treatment if COCs are detected in water supply wells in the

Lower 180-Foot Aquifer (Plate 4B). This alternative assumes that over an extended period of time, natural attenuation of contaminants through transport, biological degradation, and dispersion would eventually reduce concentrations of contaminants in groundwater, but would not provide significant containment or remediation of the contaminated groundwater. This alternative would include installation of additional background monitoring wells to 'bound' and track the plume and monitoring of existing and new wells for COCs and natural attenuation parameters for a period of 30 years. The Monitored Natural Attenuation (MNA) program would also provide a framework for evaluating and assessing exposures over time, and making cleanup decisions regarding the need for implementation of active remediation if natural attenuation processes do not reduce concentrations of COCs in the plume below aquifer cleanup levels (ACLs) within the expected timeframe. In addition, it would include implementation of a contingency for wellhead treatment if COCs are detected in water supply wells in the Lower 180-Foot Aquifer, which would protect human health by eliminating potential exposures to groundwater containing COCs.

<u>Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer)</u>; Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would provide significant protection of human health and the environment because it is expected to reduce groundwater COCs throughout the entire A-Aquifer plume to below ACLs within 15 years. In addition to containing and actively remediating the A-Aquifer plume it would include active remediation of the Upper 180-Foot Aquifer plume, and (as described under Remedial Alternative 1) (1) monitor the status of the plumes assuming the two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers would be eliminated, and (2) implement a contingency for wellhead treatment if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. The MNA program included in this alternative (as described under Remedial Alternative 1) would provide a framework for evaluating and assessing exposures over time, and making cleanup decisions regarding the need for implementation of an alternate remediation scenario if enhanced biodegradation and natural attenuation processes in the A-Aquifer and Lower 180-Foot Aquifer, and GWET in the Upper 180-Foot Aquifer do not reduce concentrations of COCs throughout the plume below ACLs within the expected timeframe.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>; Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would provide protection of human health and the environment over the long term because it is expected to

reduce groundwater COCs throughout the entire A-Aquifer plume to below ACLs within 50 years. However, because it is a ‘passive’ treatment method that only treats groundwater that passes through the PRB located in the downgradient portion of the plume, it would not capture and actively remediate (1) the upgradient portion of the plume until it migrated downgradient and passed through the PRB, or (2) the downgradient portion of the plume that had already migrated beyond the PRB location prior to its installation. In addition, the ability of the PRB to continue to effectively remediate COCs within the plume that passes through it after a period of 20 years is indeterminate and would need to be estimated in a pilot study. In addition to containing and actively remediating the A-Aquifer plume it would include active remediation of the Upper 180-Foot Aquifer plume, and the MNA program included in this alternative (as described under Remedial Alternative 1) would provide a framework for evaluating and assessing exposures over time, and making cleanup decisions regarding the need for implementation of an alternate remediation scenario if (1) the PRB does not reduce concentrations of COCs in the downgradient portion of the A-Aquifer plume for the expected duration of effectiveness, (2) the GWET in the Upper 180-Foot Aquifer does not reduce concentrations of COCs below ACLs within the expected timeframe, and (3) natural attenuation processes do not reduce concentrations of COCs throughout the remainder of the A-Aquifer and Lower 180-Foot Aquifer plumes below ACLs within the expected timeframe.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would provide protection of human health and the environment because it is expected to reduce groundwater COCs to below ACLs throughout the majority of the A-Aquifer and Upper 180-Foot plumes within 30 years. However, the downgradient portion of the A-Aquifer plume would not be captured and actively remediated under this alternative; it is assumed that natural attenuation would reduce concentrations of COCs in this area over an extended period of time as the upgradient source of COCs is remediated. The monitoring program would provide a framework for evaluating and assessing exposures over time, and making cleanup decisions regarding the need for implementation of an alternate remediation scenario if (1) the groundwater extraction and treatment systems do not reduce concentrations of COCs throughout the majority of the A-Aquifer and Upper 180-Foot Aquifer plumes, and (2) natural attenuation processes do not reduce concentrations of COCs in the downgradient portion of the A-Aquifer plume or Lower 180-Foot Aquifer below ACLs within the expected timeframe.

### 5.1.1 Comparison of Overall Protection of Human Health and the Environment

Alternative 1 would not provide significant protection of human health and the environment compared to the other alternatives because it takes no action to reduce potential exposures or remediate the plumes other than performing MNA to assess the plume status and implement wellhead treatment as a contingency if COCs are detected at water supply wells in the Lower 180-Foot Aquifer. Alternative 2 would provide the greatest degree of protection of human health and the environment within the shortest timeframe compared to the other alternatives because it is the only alternative expected to remediate and contain the entire A-Aquifer plume within 15 years and Upper 180-Foot Aquifer within a similar timeframe, while monitoring the Lower 180-Foot Aquifer plume to determine whether the wellhead treatment contingency needs to be implemented if COCs are detected in water supply wells. Alternative 3 would provide a long term level of protection through passive remediation of the A-Aquifer plume over an extended timeframe (50 years). Alternative 4 would also be protective by containing and remediating the majority of the A-Aquifer plume within approximately 30 years. Alternative 4 would provide more protection than Alternative 3 because it actively remediates the majority of the A-Aquifer plume within 30 years, compared to passively remediating only the downgradient portion of the plume within 50 years under Alternative 3.

## 5.2 Compliance with ARARs

<u>Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers)</u>: This alternative would not comply in the short term with chemical-specific and action-specific ARARs identified in Section 2.2 and summarized in Table 1 that (1) set health- or risk-based concentration limits or ranges for particular chemicals such as VOCs in groundwater associated with the OUCTP plume (i.e., MCLs), and (2) establish criteria for cleanup and abatement of the effects of discharges in a manner that promotes attainment of either background water quality, or the best water quality which is reasonable if background levels of water quality cannot be restored. However, it is assumed (1) the vertical conduits will be eliminated to prevent further migration of the source of COCs into the lower aquifers, (2) the COCs in groundwater would naturally attenuate over time to below MCLs, and (3) this alternative would eventually comply with ARARs within the 30-year timeframe for evaluating and costing alternatives (*EPA, 1988*). However, a “non-attainment zone” may need to be established to comply with such ARARs. Location-specific ARARs would be complied with during installation and monitoring of wells in biologically sensitive areas by following HMP requirements. The MNA program would provide a framework for evaluating and assessing non-attainment, and making cleanup decisions regarding the need

for implementation of active remediation if natural attenuation processes do not reduce concentrations of COCs in the plume below ACLs within the expected timeframe.

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would comply with chemical-specific and action-specific ARARs identified in Section 2.2 and summarized in Table 1 within the A-Aquifer and Upper 180-Foot Aquifer because the remedial technologies that would be implemented were estimated to be able to achieve ACL within 15 and 30 years, respectively based on groundwater modeling conducted in the RI. In the shorter term, however, a “non-attainment zone” may need to be established to comply with such ARARs in the Lower 180-Foot Aquifer which would rely on MNA. Location-specific ARARs would be complied with during installation, operation, and monitoring of wells in biologically sensitive areas by following HMP requirements. In situ remediation of the A-Aquifer plume combined with GWET in the Upper 180-Foot Aquifer and the MNA program in the Lower 180-Foot Aquifer would provide a framework for evaluating and assessing non-attainment, and making cleanup decisions regarding the need for implementation of an alternate remediation approach if these methods do not reduce concentrations of COCs in the plume below ACLs (comply with ARARs) within the expected timeframe.

Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is expected to comply with the chemical-specific and action-specific ARARs identified in Section 2.2 and summarized in Table 1 downgradient of the PRB within the A-Aquifer plume, and within the Upper 180-Foot Aquifer plume. However, a “non-attainment zone” may need to be established to comply with such ARARs in the A-Aquifer (1) in the upgradient portion of the plume until it migrated downgradient and passed through the PRB, (2) the downgradient portion of the plume that had already migrated beyond the PRB location prior to its installation, (3) after a period of 20 years if the ability of the PRB to continue to effectively remediate COCs within the plume that passes through it diminishes, and (4) in the Lower 180-Foot Aquifer which would rely on MNA. Location-specific ARARs would be complied with during installation of the PRB and installation, operation, and monitoring of wells in biologically sensitive areas by following HMP requirements. In situ remediation of the plume combined with the MNA program would provide a framework for evaluating and assessing non-attainment, and making cleanup decisions regarding the need for implementation of an alternate remediation approach if the PRB and natural attenuation processes do not reduce concentrations of COCs in the plume below ACLs (comply with ARARs) within the expected timeframe.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would comply with the chemical-specific and action-specific ARARs identified in Section 2.2 and summarized in Table 1 for the majority of the A-Aquifer plume and the entire Upper 180-Foot Aquifer plume. However, a “non-attainment zone” may need to be established to comply with such ARARs in (1) the A-Aquifer in the downgradient portion of the plume that groundwater modeling indicated would not be captured via GWET, and (2) in the Lower 180-Foot Aquifer which would rely on natural attenuation. Location-specific ARARs would be complied with during installation, operation, and monitoring of wells in biologically sensitive areas by following HMP requirements. GWET of the plume combined with the monitoring program would provide a framework for evaluating and assessing non-attainment, and making cleanup decisions regarding the need for implementation of an alternate remediation approach if GWET and natural attenuation processes do not reduce concentrations of COCs in the plume below ACLs within the expected timeframe.

### 5.2.1 Comparison of Compliance with ARARs

Alternative 1 would not comply with chemical-specific and action-specific ARARs in the foreseeable future because it takes no action to achieve MCLs or promote attainment of background water quality compared to the other alternatives. MNA would only comply with ARARs if it were determined that MCLs would be technically and economically infeasible to achieve, which is not anticipated to be the case as described in Sections 4.2 through 4.4 for the other alternatives. Alternative 1 is assumed to eventually comply with ARARs within the 30-year timeframe for evaluating and costing alternatives (*EPA, 1988*). However, a “non-attainment zone” may need to be established throughout OUCTP to comply with such ARARs. All of the alternatives would comply with location-specific ARARs during installation, operation, and monitoring of wells in biologically sensitive areas by following HMP requirements. Alternative 2 would comply with ARARs to the greatest degree because it is expected to remediate and contain the A-Aquifer and Upper 180-Foot Aquifer plumes within 15 years, thereby actively attempting to comply with ARARs within the shortest timeframe compared to the other alternatives. Alternatives 3 and 4 would comply with ARARs to a lesser degree, because both of these alternatives would not contain or remediate a portion of the plume, and a “non-attainment zone” may need to be established to comply with such ARARs in these areas. Alternative 4 would comply with

ARARs to a greater degree than Alternative 3 because it actively remediates the majority of the A-Aquifer and Upper 180-Foot Aquifer plumes within 30 years, compared to passively remediating only the downgradient portion of the plume within 50 years under Alternative 3.

## 5.3 Short-Term Effectiveness

Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers): This alternative would be effective in the short term regarding its implementability, because it would take approximately 2 months to install new monitoring wells and establish the MNA program, which would not include construction and operation of structures and equipment for remediation other than installation of additional monitoring wells and conducting MNA over a period of 30 years. Therefore, there would be limited potential risks to workers or the community, as these procedures are frequently conducted within the former Fort Ord according to approved standard operating procedures (SOPs). Potential impacts to the environment during installation and monitoring of wells in biologically sensitive areas would be mitigated by complying with HMP requirements. However, it would not be effective in the short term at achieving the remedial action objectives (RAOs) because it does not actively remediate groundwater containing COCs above ACLs within OUCTP, and instead relies on natural attenuation and monitoring the plume status over an extended period of time to assess how well it would achieve RAOs in the long term.

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would be effective in the short term regarding its implementability, because it would take approximately 6 months to install the lactate injection/recirculation wells and implement the first injection within the A-Aquifer; install a new extraction well and connect it to the existing OU2 GWTS in the Upper 180-Foot Aquifer; and install new monitoring wells and establish the MNA program throughout OUCTP. However, this alternative would include construction of a significant injection/recirculation well network (approximately 180 permanent injection/recirculation wells and injection equipment within former Fort Ord, and approximately 60 additional direct-push injection points within the toe of the plume that occurs within the City of Marina). Therefore, there would be some potential risks to workers and the community during these activities. However, these procedures are frequently conducted according to approved SOPs. Potential impacts to the environment during installation of the injection/recirculation wells and installation and monitoring of wells in biologically sensitive areas would be mitigated by complying with HMP requirements. This alternative would be effective in the short term at achieving the remedial action objectives (RAOs) because it actively remediates groundwater containing COCs above ACLs within the A-Aquifer and Upper 180-Foot Aquifer, and only relies on natural attenuation and monitoring the plume status over an extended period of time in the Lower 180-Foot Aquifer to assess how well it would achieve RAOs in the long term.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would be less effective in the short term regarding its implementability, because it would take approximately a year to conduct a pilot study to determine the effectiveness of the PRB within the A-Aquifer before it could be implemented as a full-scale remedy, which would likely take another year to implement. In addition, it would be difficult to install the PRB during both the pilot-scale and full-scale efforts because specialized equipment would be required to inject the ZVI slurry at such deep depths within sandy soils. Installation of a new extraction well and connecting it to the existing OU2 GWTS in the Upper 180-Foot Aquifer and installation of new monitoring wells and establishing the MNA program throughout OUCTP would be implementable within approximately 2 months and would be effective in the short term. There would be some potential risks to workers and the community during these activities. However, these procedures are frequently conducted according to approved SOPs. Potential impacts to the environment during installation of the injection/recirculation wells and installation and monitoring of wells in biologically sensitive areas would be mitigated by complying with HMP requirements. This alternative would not be effective in the short term at achieving the RAOs throughout the A-Aquifer, because it passively remediates only groundwater that pass through it; the remainder of the A-Aquifer plume would not achieve ACLs for an extended period of time (up to 50 years). This alternative would be effective at achieving RAOs in the short term in the Upper 180-Foot Aquifer because this plume would be actively remediated via GWET in an existing facility at OU2. This alternative relies on natural attenuation and monitoring the plume status over an extended period of time in the Lower 180-Foot Aquifer to assess how well it would achieve RAOs in the long term.

<u>Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would be effective in the short term regarding its implementability, because it would take approximately 4 months to install the extraction wells and construct the treatment system within the A-Aquifer; install a new extraction well and connect it to the existing OU2 GWTS in the Upper 180-Foot Aquifer; and install new monitoring wells and establish the MNA program throughout OUCTP. However, this alternative

would include construction of a horizontal piping network to connect two extraction wells in the A-Aquifer south of Reservation Road to the other three wells located north of Reservation Road where it is assumed the centrally located treatment plant would be, which would require more time and technical expertise than is typical for vertical extraction wells. Therefore, there would be some potential risks to workers and the community during these activities. However, these procedures are frequently conducted according to approved SOPs. Potential impacts to the environment during installation of the extraction wells and treatment system and installation and monitoring of wells in biologically sensitive areas would be mitigated by complying with HMP requirements. This alternative would be effective in the short term at achieving the RAOs because it actively remediates the majority of groundwater containing COCs above ACLs within the A-Aquifer and Upper 180-Foot Aquifer, and only relies on natural attenuation and monitoring the plume status over an extended period of time in the Lower 180-Foot Aquifer to assess how well it would achieve RAOs in the long term. However, groundwater modeling indicated this alternative would not be effective in the short term at meeting RAOs in the A-Aquifer in the downgradient portion of the plume that would not be captured via GWET.

### 5.3.1 Comparison of Short-Term Effectiveness

Alternative 1 would be the most implementable in the short term and have the fewest short-term risks associated with its implementation because it only involves installation and monitoring of MNA wells, which could be accomplished in approximately 2 months. Associated risks to workers, the community, and the environment could be easily mitigated by performing these activities in accordance with SOPs and HMP requirements. However, Alternative 1 would not be effective in the short term at achieving RAOs because it takes no action other than relying on natural attenuation processes and monitoring to achieve RAOs over an extended time period (30 years or more). Alternatives 2, 3 and 4 would all have about the same short-term risks to workers, the community, and the environment during implementation, but these are easily mitigated as described for Alternative 1 such that adequate protection would be provided. Alternative 2 would be the most effective at achieving RAOs in the short term of the alternatives that take action to remediate the A-Aquifer plume (Alternatives 2, 3, and 4); would be more effective than Alternative 3 (2 years) in the short term regarding its implementability (6 months), and would be slightly less effective in its short term implementability than Alternative 4 (4 months). Alternative 3 would be the least effective of the alternatives that take action to remediate the A-Aquifer plume in the short term regarding its implementability, because it would take approximately a year to conduct a pilot study to determine the effectiveness of the PRB within the A-Aquifer before it could be implemented as a full-scale remedy, which would likely take another year to implement. In addition, it would be difficult to install the PRB during both the pilot-scale and full-scale efforts because specialized equipment would be required to inject the ZVI slurry at such deep depths within sandy soils. Alternative 3 would also be the least effective of the alternatives that take action regarding its ability to achieve RAOs because it would only remediate the portion of the plume that passes through it, and would require up to 50 years to achieve ACLs. Alternative 4 would be more effective in the short term than Alternatives 2 and 3 in terms of its implementability, but would be less affective at achieving RAOs (30 years) in the short term as Alternative 2 (15 years), and more effective than Alternative 3 (50 years).

## 5.4 Long-Term Effectiveness and Permanence

<u>Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers)</u>: This alternative would have an unknown long-term effectiveness and permanence because it would not actively remediate or contain the plume, and the residual risk for potential groundwater users would remain until natural attenuation of COCs occurs over a period of 30 or more years. This alternative employs reliable risk controls via wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells, but does not actively reduce the risks in the portions of the plumes currently migrating offsite using a proven technology, and instead relies on long-term natural attenuation processes to reduce COCs below ACLs over a period of 30 years and monitoring to assess plume status.

<u>Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would have significant long-term effectiveness and permanence because it would actively remediate and contain the plume, and the residual risk for potential groundwater users would be reduced through enhanced biodegradation and natural attenuation of COCs to below ACLs within an expected period of 15 years in the A-Aquifer, with a similar level of effectiveness and permanence through GWET in the Upper 180-Foot Aquifer. This alternative employs reliable risk controls throughout the entire plume via in situ remediation using a proven technology demonstrated as effective for this plume in a recent pilot biotreatability study; GWET of the Upper 180-Foot Plume; long-term MNA over a period of 30 years to assess plume status throughout all three aquifers; and wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would be somewhat effective in the long term because the PRB would actively remediate and contain the downgradient portion of A-Aquifer plume for a period of approximately 20 years, and the residual risk for

potential groundwater users during this time would be reduced through PRB treatment and natural attenuation of COCs to below ACLs. However, it is not anticipated to provide permanence because (1) the reactive materials (ZVI) only have an expected effective duration of 20 years compared to the 50 years anticipated to be required to achieve MCLs, and (2) it relies on natural attenuation processes to reduce COCs below ACLs in the majority of the plume that occurs upgradient of the PRB location. There would be a higher level of effectiveness and permanence through GWET in the Upper 180-Foot Aquifer. This alternative employs risk controls of indeterminate reliability in a portion of the A-Aquifer plume (PRB's effectiveness must be demonstrated in a pilot study); reliable risk controls via GWET of the Upper 180-Foot Plume; and less reliable controls via long-term MNA over a period of 30 years to assess plume status throughout all three aquifers, although wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would reduce risks.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would be effective in the long term and provide permanence to a significant degree because it would actively remediate and contain the majority of the A-Aquifer and Upper 180-Foot Aquifer plumes for a period of approximately 30 years, and the residual risk for potential groundwater users during this time would be reduced through GWET to below ACLs. However, it would not employ reliable risk controls to remediate the downgradient portion of the A-Aquifer plume that is migrating offsite or the Lower 180-Foot Aquifer, and instead relies on long-term monitoring over a period of 30 years to assess the plume status throughout all three aquifers, although wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would reduce risks.

### 5.4.1 Comparison of Long Term Effectiveness and Permanence

Alternative 1 would have unknown long-term effectiveness and permanence because it would not actively remediate or contain the plume, and the residual risk for potential groundwater users would remain until natural attenuation of COCs occurs over a period of 30 or more years, although monitoring and wellhead treatment of water supply wells if COCs are detected would employ reliable risk controls. Alternative 2 would provide the greatest degree of long-term effectiveness and permanence through active remediation and achievement of ACLs within 15 years for the A-Aquifer and Upper 180-Foot Aquifers using proven technologies, combined with MNA for a period of 30 years. Alternative 3 would not provide significant long-term effectiveness or permanence because (1) it only remediates the downgradient portion of the A-Aquifer plume that passes through the PRB and relies on natural attenuation of the remaining portions,

(2) the PRB may only be effective in remediating COCs below ACLs for a period of 20 years, and (3) remediation using this technology is anticipated to take 50 years to achieve ACLs in the A-Aquifer. GWET in the Upper 180-Foot Aquifer and MNA in the Lower 180-Foot Aquifer would be the same as for Alternative 2. Alternative 4 (30 years) would provide significantly more long-term effectiveness and permanence than Alternative 3 (50 years) because it actively remediates and contains the majority of the A-Aquifer and Upper 180-Foot Aquifer plumes via GWET to below ACLs within approximately 30 years. However, it would not actively remediate the downgradient portion of the A-Aquifer plume that is migrating offsite and instead relies on natural attenuation processes to reduce COCs below ACLs in this portion of the plume and in the Lower 180-Foot Aquifer.

## 5.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

<u>Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers)</u>: This alternative takes no action to treat groundwater containing COCs and therefore would not actively reduce the toxicity, mobility, or volume of COCs through treatment. Some reduction in these parameters would be achieved via natural attenuation processes occurring within OUCTP over an extended period of time, and if COCs are detected in water supply wells in the Lower 180-Foot Aquifer and wellhead treatment is implemented.

<u>Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would actively reduce the toxicity, mobility, and volume of COCs and achieve reduction to below ACLs throughout the entire plume via in situ enhanced biodegradation treatment in the A-Aquifer, GWET in the Upper 180-Foot Aquifer, and natural attenuation processes throughout OUCTP and specifically in the Lower 180-Foot Aquifer, with additional reduction in this aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. This alternative employs proven technologies demonstrated as effective for these plumes and long-term MNA over a period of 30 years to verify reduction of these parameters.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would actively reduce the toxicity, mobility, and volume of COCs within the downgradient portion of the A-Aquifer plume for a period of approximately 20 years (the expected effective lifespan of the PRB), and could achieve reduction to below ACLs within 50 years through in situ PRB treatment and natural

attenuation processes. However, it is only anticipated to reduce these parameters directly downgradient of the PRB. Therefore, reduction of these parameters throughout the majority of the plume would rely on natural attenuation processes to reduce COCs below ACLs over an extended period of time in the A-Aquifer and the Lower 180-Foot Aquifer, with additional reduction in this aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. This alternative employs an unproven technology (pilot study would be required to verify effectiveness) for downgradient plume migration control and long-term MNA over a period of 30 years to verify reduction of these parameters.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would actively reduce the toxicity, mobility, and volume of COCs and achieve reduction to below ACLs within 30 years throughout the majority of the A-Aquifer upgradient plume and Upper 180-Foot Aquifer through GWET, and could achieve reduction to below ACLs in the downgradient portion of the plume and the Lower 180-Foot Aquifer through natural attenuation processes over an extended period of time, with additional reduction in this aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. This alternative employs a proven technology and long-term MNA over a period of 30 years to verify reduction of these parameters.

### 5.5.1 Comparison of Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs through treatment to an appreciable extent except as it may occur through natural attenuation processes over an extended period of time, with some additional reduction in the Lower 180-Foot Aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. Alternative 2 would provide the greatest reduction in toxicity, mobility, and volume of COCs through active remediation and plume containment via in situ enhanced biodegradation in the A-Aquifer, GWET in the Upper 180-Foot Aquifer, and MNA with some additional reduction in the Lower 180-Foot Aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. Alternative 3 would provide reduction throughout the majority of the A-Aquifer plume over a long timeframe (50 years as compared to 15 years for Alternative 2 and 30 years for Alternative 4) but would rely on natural attenuation process within the non-PRB portions of the plume to reduce these parameters over an extended period of time; GWET in the Upper 180-Foot Aquifer; and MNA with some additional reduction in the Lower 180-Foot Aquifer if COCs are detected in water supply wells and wellhead treatment is implemented. Alternative 4 would provide a similar level of reduction as Alternative 2 throughout the majority of the plume over a longer timeframe.

## 5.6 Implementability

Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers): This alternative would be easy to implement from a technical perspective because it only involves monitoring well installation and long-term MNA and reporting, for which the required equipment, skilled labor resources, permits and approvals would be readily available. However, this alternative is anticipated to be difficult to implement from an administrative perspective (gaining regulatory approval and community acceptance) because it would not comply with ARARs nor actively remediate the plume (except through natural attenuation over an extended period of time), which is migrating offsite. However, if a “non-attainment zone” is established for the duration that MNA would take to achieve ACLs and the other alternatives are determined in the remedial design phase to be technically or economically infeasible, this alternative would be easy to implement from both perspectives.

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would require a moderate level of effort to implement from a technical perspective because it involves installation of several hundred injection points/recirculation wells and equipment, extraction wells, piping, and monitoring wells, as well as long-term treatment system operations and maintenance, and long-term MNA and reporting over a period of 30 years. However, the required equipment, skilled labor resources, permits and approvals to implement this alternative would be readily available. This alternative is anticipated to be moderately easy to implement from an administrative perspective (gaining regulatory approval and community acceptance) because it would provide the most protection human health and the environment and comply with ARARs through active remediation of the A-Aquifer and Upper 180-Foot Aquifer plumes using proven technologies, and would also include long-term MNA over a period of 30 years to assess the status of the all three aquifer plumes, as well as a contingency for wellhead treatment in the Lower 180-Foot Aquifer if COCs are detected in water supply wells. Creating large anaerobic zones would have a substantial impact on the subsurface environment and greatly alter local geochemical balances. Full scale applications of in situ enhanced biodegradation systems have experienced numerous operational difficulties, such as aquifer fouling. This potential will be further evaluated during the remedial design phase if this technology is selected for implementation; reintroduction of oxygen downgradient of the treatment area to restore the aerobic balance of the aquifer could be considered if potential impacts are identified (e.g., using air sparging/recirculation wells).

Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would require a high level of effort to implement from a technical perspective because it involves conducting a field-scale pilot study to ascertain its site-specific effectiveness, followed by a full-scale installation of a deep barrier that must be tied into the underlying FO-SVA using specialized techniques and placement of iron materials using innovative slurry injection techniques. It also includes installation of an extraction wells and GWET for the Upper 180-Foot Aquifer, as well as long-term treatment system operations and maintenance, and long-term MNA and reporting for a period of 30 years. However, the required equipment, skilled labor resources, permits and approvals to implement this alternative are assumed to be available. This alternative is anticipated to be moderately difficult to implement from an administrative perspective (gaining regulatory approval and community acceptance) because it (1) would only remediate groundwater and comply with ARARs in the portion of the plume immediately downgradient of the PRB in the short term, and (2) would not have long-term effectiveness and permanence due to the limited lifespan of the treatment media (approximately 20 years as compared to the 50 years estimated to be required to achieve ACLs based on groundwater modeling). This alternative would also include long-term MNA over a period of 30 years to assess the status of the all three aquifer plumes, as well as a contingency for wellhead treatment in the Lower 180-Foot Aquifer if COCs are detected in water supply wells.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative would require a moderate level of effort to implement from a technical perspective because it involves installation of extraction and reinjection wells, long-term GWET system operations and maintenance, and long-term MNA and reporting. However, the required equipment, skilled labor resources, permits and approvals to implement this alternative would be readily available. This alternative is anticipated to be moderately difficult to implement from an administrative perspective (gaining regulatory approval and community acceptance) because it (1) would only remediate groundwater and comply with ARARs in the upgradient portion of the A-Aquifer plume, and (2) would rely on "pump and treat" technology to achieve ACLs, which are often technically and economically infeasible to achieve in such high-flow aquifers and over such large plume sizes. This alternative would also include long-term MNA over a period of 30 years to assess the status of the all three aquifer plumes, as well as a contingency for wellhead treatment in the Lower 180-Foot Aquifer if COCs are detected in water supply wells.

### 5.6.1 Comparison of Implementability

Alternative 1 would be easy to implement from a technical perspective and is anticipated to be difficult to implement from an administrative perspective because it does not involve active remediation of the plume. Alternative 2 would be moderately easy to implement from both technical and administrative perspectives compared to the other alternatives, because it uses proven technologies that have been demonstrated as effective and involves active remediation of the plumes. Alternative 3 would be more difficult to implement from both technical and administrative perspectives because it does not involve active remediation of the entire plume or have significant long-term effectiveness of permanence. Alternative 4 would be moderately easy to implement from a technical perspective because it involves active remediation of the majority of the plumes using proven GWET technology, but would be moderately difficult to implement from an administrative perspective because it (1) would only remediate groundwater and comply with ARARs in the upgradient portion of one of the plumes, and (2) would rely on “pump and treat” technology to achieve ACLs, which are often technically and economically infeasible to achieve in such high-flow aquifers and over such large plume sizes.

## 5.7 Cost

Cost estimating assumptions, unit costs, and real discount rates (that vary according to the period of performance) that are associated with implementation of the remedial alternatives are provided in Appendix A. Capital costs, operations and maintenance (O&M) costs, and total net present value (NPV) implementation costs for each of the alternatives evaluated herein are presented in Tables A1—A5, respectively.

Costs associated with the Upper 180-Foot Aquifer GWET alternative if it is selected for implementation would be estimated as part of optimization of the existing OU2 GWET system during the remedial design phase. Costs associated with contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would be estimated during the remedial design phase for implementation of the selected alternative.

Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers): Capital costs associated with planning and installing up to 30 additional monitoring wells to ‘bound’ the plumes are estimated at approximately $558,000. Operations and maintenance costs for 30 years of monitoring and reporting are estimated at approximately $2.19 million, for a total estimated 30-year net present value (NPV) cost of $2.75 million. Costing assumptions and estimates for this alternative are presented in Table A1 of Appendix A.

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): Capital costs associated with installing the lactate injection and recirculation treatment system and additional monitoring wells, and conducting the first lactate injection event are estimated at approximately $4.63 million. Treatment system operations and maintenance costs for 15 years and 20 years of monitoring and reporting are estimated at approximately $4.90 million, for a total estimated 20-year NPV cost of $9.54 million. Costing assumptions and estimates for this alternative are presented in Table A2 of Appendix A.

Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): Capital costs associated with installing the PRB and additional monitoring wells are estimated at approximately $8.73 million. Operations and maintenance and monitoring and reporting costs for 30 years are estimated at approximately $4.42 million, for a total estimated 30-year NPV cost of $13.15 million. Costing assumptions and estimates for this alternative are presented in Table A3 of Appendix A.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): Capital costs associated with installing the extraction, treatment, and reinjection system and additional monitoring wells are estimated to range from approximately $2.38 to $2.45 million, depending on whether activated carbon or air stripping treatment is selected for implementation during the remedial design phase. Treatment system operations and maintenance costs for 30 years of monitoring and reporting range from approximately $11.06 to $17.46 million depending on the treatment method, for a total 30-year NPV estimated cost ranging from $13.44 to $19.92 million. Costing assumptions and estimates for this alternative are presented in Tables A4 and A5 of Appendix A for the activated carbon and air stripping treatment options, respectively.

### 5.7.1 Comparison of Cost

#### *Comparison of Capital Costs*

Alternative 1 has the lowest capital cost associated with its implementation of $558,000, but does not take action to actively remediate OUTCP. Of the alternatives that take action to remediate OUCTP, Alternative 4 has the next lowest capital cost of \$2.38 to \$2.45 million, followed by \$4.63 and \$8.73 million for Alternatives 2 and 3, respectively.

***Comparison of Long Term (30-Year) Operations and Maintenance (O&M) Costs***

Alternative 1 has the lowest long term O&M cost of \$2.19 million, but does not take action to actively remediate OUCTP. Of the alternatives that take action to remediate OUCTP, Alternative 3 has the next lowest long term O&M cost of \$4.42 million, followed by Alternative 2 (\$4.63 million) and Alternative 4 (\$11.06 to \$17.46 million).

***Comparison of Total Net Present Value (NPV) Costs***

Alternative 1 has the lowest total NPV cost of \$2.75 million, but does not take action to actively remediate OUCTP. Alternative 2 has the lowest total NPV cost of the alternatives that take action to remediate the OUCTP plumes of \$9.54 million. Alternatives 3 and 4 have the highest total NPV costs of the alternatives that take action of \$13.15 million and \$13.44 to \$19.92 million, respectively.

## 5.8 Regulatory Acceptance

Regulatory acceptance will be addressed in the OUCTP RI/FS ROD once comments on the RI/FS report and Proposed Plan have been received.

<u>Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers)</u>: This alternative is not likely to be acceptable to the regulatory agencies because it does not take action to achieve ACLs in a timely manner, and would not comply with ARARs discussed in Section 2.2 and summarized in Table 1, nor actively remediate the plume (except through natural attenuation over an extended period of time), which is migrating offsite. However, if a “non-attainment zone” is established for the duration that MNA would take to achieve ACLs and the other alternatives are determined in the remedial design phase to be technically or economically infeasible, this alternative may be acceptable to the agencies.

<u>Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is likely to be acceptable to the regulatory agencies because it would protect human health and the environment; would comply with ARARs discussed in Section 2.2 and summarized in Table 1; and takes action both in the short and long term to achieve ACLs in both the A-Aquifer and Upper 180-Foot Aquifers, while including contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): It is not known whether this alternative would be acceptable to the regulatory agencies because it would only protect human health and the environment and comply with all of the ARARs discussed in Section 2.2 and summarized in Table 1 immediately downgradient of the PRB in the A-Aquifer over an extended period of time that would have to be verified in a pilot study prior to full-scale implementation; currently it is only estimated to be effective for a period of 20 years, and the required time to achieve ACLs using a PRB is estimated as 50 years based on groundwater modeling. However, if a "non-attainment zone" is established for the duration of the period it would take to achieve ACLs in the A-Aquifer and the other A-Aquifer alternatives are determined in the remedial design phase to be technically or economically infeasible, this alternative may be acceptable to the agencies. This alternative also takes action both in the short and long term to achieve ACLs in the Upper 180-Foot Aquifer via GWET, while including contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

<u>Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is likely to be acceptable to the regulatory agencies because it would protect human health and the environment; would comply with ARARs discussed in Section 2.2 and summarized in Table 1; and takes action both in the short and long term to achieve ACLs in both the A-Aquifer and Upper 180-Foot Aquifers via GWET, while including contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells. However, a portion of the A-Aquifer plume would not be captured and remediated under this alternative, and it is often found that achieving ACLs using "pump and treat" technology is technically and economically infeasible. However, if a "non-attainment zone" is established for the duration of the period it would take to achieve ACLs in the A-Aquifer and the other A-Aquifer alternatives are determined in the remedial design phase to be technically or economically infeasible, this alternative may be acceptable to the agencies. This alternative also takes action both in the short and long term to achieve ACLs in the Upper 180-Foot Aquifer via GWET, while including contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

### 5.8.1 Comparison of Regulatory Acceptance

Alternative 1 would not likely be acceptable to the agencies because it takes no action to contain or remediate the plume other than to monitor its status through MNA and provide contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells, that is, unless a “non-attainment zone” is established within OUCTP because the other remedial alternatives are determined to be technically or economically infeasible for implementation. Alternative 2 would likely be the most acceptable to the agencies because it is the only alternative that would remediate the entire A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs within the shortest timeframe, while protecting human health and the environment and complying with ARARs, and also providing long term MNA and contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells. Alternatives 3 and 4 would likely be less acceptable than Alternative 2 because they do not meet the evaluation criteria to the same extent. Regulatory acceptance and preferences would be known in more detail after agency comments are received on the draft RI/FS report and ultimately would be determined in the OUCTP RI/FS ROD.

## 5.9 Community Acceptance

Community acceptance will be addressed in the OUCTP RI/FS ROD once comments on the RI/FS report and Proposed Plan have been received.

<u>Remedial Alternative 1—No Action with Monitored Natural Attenuation (All Aquifers)</u>: It is anticipated that the public would not accept this alternative and would have a preference that some type of active remediation be implemented to mitigate risks and comply with ARARs unless it is determined that the other remedial alternatives are technically or economically infeasible to implement.

<u>Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is likely to be acceptable to the public because it is the only alternative that would remediate the entire A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs within the shortest timeframe (15 years), while protecting human health and the environment and complying with ARARs, and also providing long term MNA and contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

<u>Remedial Alternative 3—In Situ Permeable Reactive Barrier (A-Aquifer)</u>: Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural

Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is likely to be less acceptable to the public because it would only be effective in the short term immediately downgradient of the A-Aquifer plume for a period of 20 years, and the required time to achieve ACLs using a PRB is estimated as 50 years. The other components of this alternative for the Upper and Lower 180-Foot Aquifers are likely to be acceptable as stated above for Remedial Alternative 2.

Remedial Alternative 4—Groundwater Extraction and Treatment (A-Aquifer): Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer): This alternative is likely to be acceptable to the public because it would remediate the majority of the A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs within 30 years, while protecting human health and the environment and complying with ARARs, and also providing long term MNA and contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells. However, a portion of the A-Aquifer plume would not be captured and remediated under this alternative, and it is often found that achieving ACLs using “pump and treat” technology is technically and economically infeasible.

### 5.9.1 Comparison of Community Acceptance

Alternative 1 would not likely be acceptable to the public because it takes no action to contain or remediate the plume other than to monitor its status through MNA and provide contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells. Alternative 2 would likely be the most acceptable to the public because it is the only alternative that would remediate the entire A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs within the shortest timeframe, while protecting human health and the environment and complying with ARARs, and also providing long term MNA and contingent wellhead treatment at water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells. Alternatives 3 and 4 would likely be less acceptable than Alternative 2 because they do not meet the evaluation criteria to the same extent. Community acceptance and preferences would be known in more detail after public comments are received on the OUCTP RI/FS report and Proposed Plan, and ultimately would be determined in the RI/FS ROD.

# 6.0 PRELIMINARILY IDENTIFIED PREFERRED REMEDIAL ALTERNATIVE

This section summarizes and presents the rationale for selection of the preliminarily identified preferred remedial alternative for implementation within OUCTP based on the evaluation and comparison of alternatives presented in Section 5.0.

## 6.1 Summary of the Preliminarily Identified Preferred Remedial Alternative

Remedial Alternative 2 was preliminarily identified as the preferred remedial alternative for OUCTP, and is summarized as follows:

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer):

This alternative presents (1) an in situ remediation scenario for treatment and migration control of the A-Aquifer groundwater plume via a large network of enhanced biodegradation injection points throughout the entire plume for a period of 15 years with 5 years of follow-up monitoring to assess the potential ‘rebound’ of COCs above ACLs (Plate 5); (2) groundwater extraction and treatment and migration control of the Upper 180-Foot Aquifer via extraction wells (Plate 8) and treatment within the existing Operable Unit 2 Groundwater Extraction and Treatment System (OU2 GWTS); and (3) monitored natural attenuation of all three aquifers for a period of 30 years, with a contingency for wellhead treatment if COCs are detected in water supply wells within the Lower 180-Foot Aquifer (Plate 4B).

***A-Aquifer***

The effectiveness of in situ enhanced biodegradation via injection and recirculation of lactate in reducing CT concentrations in the A-Aquifer has been demonstrated in site-specific bench-scale and pilot treatability studies as described in Section 3.9 of the RI (Volume I) and summarized in Section 3.2.2. The groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the A-Aquifer CT-plume to below aquifer cleanup levels (ACLs) within a time period of approximately 15 years, with 6 lactate injection events occurring approximately every 2.5 years. Plate 5 illustrates the 10 injection locations, and simulations of CT concentrations within the A-Aquifer after the first injection event (Year 1) and the sixth injection event (Year 15).

The results of the groundwater modeling for this scenario simulated the dechlorination of CT under favorable chemical conditions induced by the addition of an electron donor such as lactate in sufficient quantity and number of locations to remediate the A-Aquifer CT plume as shown on Plate 5 and summarized as follows:

- A line of 10 injection locations that span the width of the plume aligned perpendicular to groundwater flow, and consist of lactate injection points located every 40 feet, each with a radius of influence of approximately 20—60 feet.
- The majority of injection points would be installed to a depth of approximately 100 feet bgs as permanent 4-inch diameter recirculation wells (as were demonstrated to be effective in the pilot biotreatability study) that would aid in the distribution of lactate throughout the aquifer and could be reinjected with lactate as often needed to maintain favorable biodegradation rates within the aquifer (approximately every 2.5 years).
- The remainder of injection points located in the portion of the plume that has migrated offsite into the City of Marina (referred to as the downgradient ‘toe of the plume’) would be installed using direct-push injection techniques due to constraints on installing and constructing permanent wells and an aboveground treatment system within developed areas, and would have to be reinjected as often needed to maintain favorable biodegradation rates within the aquifer (approximately every 2.5 years).
- Approximately 250 gallons of a 60% sodium lactate solution would be injected at each injection point every 2.5 years until concentrations of COCs are at or below ACLs or are asymptotic (no longer declining) near ACLs (approximately 15 years, or a total of 6 injection events).
- The two vertical conduits that are allowing contaminated groundwater to migrate from the A-Aquifer into the Upper 180-Foot and Lower 180-Foot Aquifers into this aquifer will be eliminated as follows: (a) Monitoring Well MW-B-13-A will be destroyed (grouted and sealed); and (b) the Mini-Storage well will be destroyed (grouted and sealed), or if it is determined that it could be converted into an extraction well (EW) that would provide additional containment of the plume, groundwater extracted from this well would be treated at the well-head (via activated carbon or air stripping as described in Section 3.3.2) and tied into the existing piping conveyance system that transfers the treated water into the existing water supply system.

- Up to 30 additional "point of compliance" monitoring wells would be installed to provide additional monitoring locations that would trigger reassessment of the remedy or implementation of a contingency plan if COCs are detected in water supply wells in the Lower 180-Foot Aquifer. A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells.

- Treatment system monitoring would be conducted for VOCs and natural attenuation parameters throughout the duration of treatment (15 years) and an additional 5 years of follow-up monitoring to assess the potential for concentrations of COCs to 'rebound' after treatment is discontinued, for a total duration of 20 years. Groundwater monitoring of the OUCTP MWs would be conducted for a period of 30 years.

- Natural attenuation indicator data would be analyzed to gauge the level of enhanced biodegradation within the aquifer and determine the need for and estimate the time between lactate reinjection events.

- Capital costs associated with installing the lactate injection and recirculation treatment system and additional monitoring wells, and conducting the first lactate injection event are estimated at approximately $4.63 million. Treatment system operations and maintenance costs for 15 years and 20 years of monitoring and reporting are estimated at approximately $4.90 million, for a total estimated 20-year NPV cost of $9.54 million. Costing assumptions and estimates for this alternative are presented in Table A2 of Appendix A.

### *Upper 180-Foot Aquifer*

This alternative presents a containment approach that includes a pumping scenario for migration control of the groundwater plume with aboveground treatment and reinjection of treated water back into the aquifer. This alternative assumes the newly installed groundwater extraction well EW-OU2-07-180 that is a component of the optimized Operable Unit 2 Groundwater Treatment System (OU2 GWTS) would be pumped at a total flow rate of approximately 150 gallons per minute (gpm) for capture of the majority of the Upper 180-Foot Aquifer plume as shown on Plate 8. The extracted water would be collected and treated at the existing aboveground central process and control area of the OU2 GWTS.

As shown on Plate 8, which illustrates the well locations, particle tracking streamlines, and concentrations of COCs within the plume from the most recent groundwater monitoring data (September 2004) that were used in the simulation, the results of the groundwater modeling simulation of this alternative indicated it would be effective in containing and remediating the majority of the Upper 180-Foot Aquifer plume to below aquifer cleanup levels (ACLs) within a time period of approximately 30 years (Scenario 2; Section 9.0 and Appendix F of the RI; Volume I) as follows:

- The newly installed groundwater extraction well EW-OU2-07-180 would be pumped at a total flow rate of approximately 150 gpm. Optimization procedures would need to be implemented within the OU2 GWTS to incorporate the additional flow of 150 gpm into the current treatment system, which has an approximate capacity limitation of 1,000 gpm.

- The extracted groundwater would require treatment within the existing OU2 GWTS to meet reinjection standards (discharge limits) for the COCs listed in Table 2, which are anticipated to be MCLs or detection limits using EPA Test Method 8260.

- A pipeline between the EW and the OU2 GWETS would need to be constructed to allow transfer of the extracted groundwater to the treatment plant. Treated effluent would be reinjected back into the aquifer through the reinjection wells associated with the existing OU2 GWTS.

- Implementation of this alternative if it is selected would be conducted as part of optimization of the existing OU2 GWET system during the remedial design phase. Costs associated with installing additional extraction wells, piping conveyance to tie these wells into the existing OU2 GWETS, and additional treatment capacity to treat groundwater extracted from this aquifer would be estimated during the remedial design associated with the optimization of the OU2 GWETS.

### *Lower 180-Foot Aquifer*

This alternative presents a monitoring and contingency approach that includes a pumping scenario for this aquifer that assumes:

- The plume(s) would naturally attenuate over a period of approximately 30 years to meet RAOs.

- Chemical concentrations in groundwater and offsite plume migration would not increase in a statistically significant manner.

- A contingency plan would be developed for well-head treatment of groundwater (via activated carbon or air stripping as described in Section 3.3.2) being extracted from potable water supply wells if COCs associated with OUCTP (Table 2) are detected in these wells (Plate 4B).

- Costs associated with contingent wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells would be estimated during the remedial design phase for implementation of the selected alternative.

The rationale for selection of the preliminarily identified preferred remedial alternative is presented below.

## 6.2 Rationale for Selection of the Preliminarily Identified Preferred Remedial Alternative

Remedial Alternative 2—In Situ Enhanced Biodegradation (A-Aquifer); Groundwater Extraction and Treatment Via the Existing OU2 GWTS (Upper 180-Foot Aquifer); No Action with Monitored Natural Attenuation and Wellhead Treatment Contingency (Lower 180-Foot Aquifer), is preliminarily identified as the preferred alternative for implementation within OUCTP plume for the following reasons:

<u>Overall Protection of Human Health and the Environment:</u> This alternative would provide the greatest degree of protection of human health and the environment within the shortest timeframe compared to the other alternatives because it is the only alternative expected to remediate to below ACLs and contain the entire A-Aquifer plume within 15 years and Upper 180-Foot Aquifer within a similar timeframe, while monitoring the Lower 180-Foot Aquifer plume to determine whether the wellhead treatment contingency needs to be implemented if COCs are detected in water supply wells.

<u>Compliance with ARARs</u>: This alternative is the only alternative evaluated that would comply with all ARARs identified in Section 2.2 and summarized in Table 1. In situ remediation of the A-Aquifer plume combined with GWET in the Upper 180-Foot Aquifer and the MNA program in the Lower 180-Foot Aquifer would provide a framework for evaluating and assessing attainment of ARARs, and making cleanup decisions regarding the need for implementation of an alternate remediation approach if these methods do not reduce concentrations of COCs in the plume below ACLs (comply with ARARs) within the expected timeframe.

<u>Short-Term Effectiveness</u>: This alternative would be effective in the short term regarding its implementability, because it would take approximately 6 months to install the lactate injection/recirculation wells and implement the first injection within the A-Aquifer; install a new extraction well and connect it to the existing OU2 GWTS in the Upper 180-Foot Aquifer; and install new monitoring wells and establish the MNA program throughout OUCTP. However, this alternative would include construction of a significant injection/recirculation well network (approximately 180 permanent injection/recirculation wells and injection equipment within former Fort Ord, and approximately 60

additional direct-push injection points within the toe of the plume that occurs within the City of Marina). Therefore, there would be some potential risks to workers and the community during these activities. However, these procedures are frequently conducted according to approved SOPs. Potential impacts to the environment during installation of the injection/recirculation wells and installation and monitoring of wells in biologically sensitive areas would be mitigated by complying with HMP requirements. This alternative would be the most effective in the short term at achieving the remedial action objectives (RAOs) because it actively remediates groundwater containing COCs above ACLs within the A-Aquifer and Upper 180-Foot Aquifer, and only relies on natural attenuation and monitoring the plume status over an extended period of time in the Lower 180-Foot Aquifer to assess how well it would achieve RAOs in the long term.

<u>Long-Term Effectiveness and Permanence</u>: This alternative would have the greatest long-term effectiveness and permanence because it would actively remediate and contain the plumes, and the residual risk for potential groundwater users would be reduced through enhanced biodegradation and natural attenuation of COCs to below ACLs within an expected period of 15 years in the A-Aquifer, with a similar level of effectiveness and permanence through GWET in the Upper 180-Foot Aquifer. This alternative employs reliable risk controls throughout the entire plume via in situ remediation using a proven technology demonstrated as effective for this plume in a recent pilot biotreatability study; GWET of the Upper 180-Foot Plume; long-term MNA over a period of 30 years to assess plume status throughout all three aquifers; and wellhead treatment of water supply wells in the Lower 180-Foot Aquifer if COCs are detected in these wells.

<u>Reduction of Toxicity, Mobility, and Volume Through Treatment</u>: This alternative would actively reduce the toxicity, mobility, and volume of COCs to the greatest extent of all the alternatives evaluated, and is the only alternative that would remediate the entire A-Aquifer and Upper 180-Foot Aquifer plumes to below ACLs in under 30 years. This alternative employs proven technologies demonstrated as effective for these plumes, and long-term MNA over a period of 30 years to verify reduction of these parameters.

<u>Implementability</u>: This alternative would require a moderate level of effort to implement from a technical perspective because it involves installation of several hundred injection points/recirculation wells and long-term MNA and reporting. However, the required equipment, skilled labor resources, permits and approvals to implement this alternative would be readily available, and the level of effort is similar to the other alternatives evaluated. This alternative is anticipated to be moderately easy to implement from an administrative perspective (gaining regulatory approval and community acceptance) because it would be the only alternative evaluated that would comply with all ARARs and actively remediate the entire

A-Aquifer and Upper 180-Foot aquifer plumes using proven technologies, and would also include long-term MNA over a period of 30 years to assess the status of the plumes and wellhead treatment of water supply wells if COCs are detected in these wells within the Lower 180-Foot Aquifer.

Cost: Capital costs associated with implementation of this alternative include those for installation of several hundred injection points/recirculation wells; startup of the lactate injection and recirculation system; the first lactate injection event, system monitoring, sampling, and reporting; and monitoring well installation, sampling, and reporting. Annual O&M costs associated with reinjection of lactate over 15 years and conducting MNA and reporting for a period of 30 years are approximately $4.9 million. The total NPV cost for this alternative is estimated at $9.54 million for a period of 30 years. Aside from the No Action with Monitored Natural Attenuation Alternative, which would not actively remediate or contain the plume in the foreseeable future, this alternative has the lowest total NPV cost of all the alternatives evaluated.

Regulatory Acceptance: Regulatory acceptance will be addressed in the OUCTP RI/FS ROD once comments on the RI/FS report and Proposed Plan have been received. However, this alternative is likely to be the most acceptable to the regulatory agencies of all the alternatives evaluated because it would protect human health and the environment; would comply with all ARARs; and takes action both in the short and long term to achieve ACLs in the A-Aquifer and Upper 180-Foot Aquifer to the greatest extent of all the alternatives evaluated. It also provides long term monitoring of all three aquifers, and a contingency for wellhead treatment if COCs are detected in water supply wells in the Lower 180-Foot Aquifer.

Community Acceptance: Community acceptance will be addressed in the OUCTP RI/FS ROD once comments on the RI/FS report and Proposed Plan have been received. However, this alternative is likely to be the most acceptable to the public of all the alternatives evaluated because it would protect human health and the environment; would comply with all ARARs; and takes action both in the short and long term to achieve ACLs in the A-Aquifer and Upper 180-Foot Aquifer to the greatest extent of all the alternatives evaluated. It also provides long term monitoring of all three aquifers, and a contingency for wellhead treatment if COCs are detected in water supply wells in the Lower 180-Foot Aquifer.

# 7.0 APPROVAL PROCESS

The approval process for the OUCTP RI/FS includes the following components:

- Prepare the RI/FS report with regulatory agency and public review of the Draft and Draft Final reports.
- Prepare a Proposed Plan that summarizes the results of the RI, RA, and FS.
- Solicit public comments on the Proposed Plan during a 30-day review period.
- Provide an opportunity for a public meeting on the Proposed Plan where written and verbal comments can be submitted.
- Prepare the Record of Decision (ROD) that (1) summarizes the results of the RI, HHRA, and FS, (2) includes a Responsiveness Summary that summarizes any public comments received on the Proposed Plan, and Army responses to comments, and (3) specifies the details of the selected remedy(s), including plans for development and submittal of remedial design documents as appropriate.
- Receive EPA and RWQCB approval of the ROD, and review by DTSC.
- Announce the decision regarding the remedy selection in a local major newspaper and place copies of the RI/FS, Proposed Plan, and ROD in the Administrative Record and local information repositories.

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# TABLES

# PLATES

## DISTRIBUTION

Draft Final
Operable Unit Carbon Tetrachloride Plume
Groundwater Remedial Investigation/
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Volume III – Feasibility Study

October 28, 2005

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