# FINAL
# PROPOSED PLAN
# FOR LHAAP-18/24
# BURNING GROUND NO. 3 AND
# UNLINED EVAPORATION POND

ISSUED BY: U.S. ARMY

**Longhorn Army Ammunition Plant**
**Karnack, Texas**

**February 2019**

## Table of Contents



## List of Figures



## List of Tables

## INTRODUCTION

This Proposed Plan identifies the Preferred Alternative for cleaning up the contaminated soil and groundwater at Longhorn Army Ammunition Plant (LHAAP)-18/24; the site of Burning Ground No. 3 (LHAAP-18) and the Unlined Evaporation Pond (LHAAP-24). The primary purpose of the Proposed Plan is to facilitate public involvement in the remedy selection process. The Proposed Plan provides the public with basic background information about LHAAP-18/24, identifies the preferred final remedy (page 22) to remediate soil and groundwater contamination at the site, explains the rationale for the preference, and describes other remedial options considered. The preferred alternative for LHAAP-18/24 is Alternative 5: enhanced groundwater extraction and treatment, Land Use Controls (LUCs), enhanced in-situ bioremediation (EISB) inside and outside of the containment area in the shallow zone and in the Wilcox Formation, unsaturated soil excavation and off-site disposal, and thermal dense non-aqueous phase liquid (DNAPL) removal.

The U.S. Army is issuing this Proposed Plan for public review, comment, and participation to fulfill part of its public participation responsibilities under Section 117(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (42 U.S.C. §9601 et seq.) and under Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)(40CFR Part 300). CERCLA prescribes a step-wise progression of activities to respond to risk posed by contaminated sites (**Figure 1**).

Dates to remember: April 2 to May 2, 2019
**MARK YOUR CALENDER**

**PUBLIC COMMENT PERIOD:**
April 2 to May 2, 2019
The U.S. Army will accept written comments on the Proposed Plan during the public comment period.

**PUBLIC MEETING:** The U.S. Army will hold a public meeting to explain the Proposed Plan for LHAAP-18/24. Oral and written comments will be accepted at the meeting. The meeting will be held on April 25, 2019 from 6:00 p.m. to 7:30 p.m. at Karnack Community Center.

For more information, see the Longhorn AAP website: http://www.longhornaap.com/ or visit the Administrative Record at the following location:

Marshall Public Library
300 S. Alamo
Marshall, Texas 75670

Business Hours:
Monday – Thursday (10:00 a.m. – 8:00 p.m.)
Friday – Saturday (10:00 a.m. – 5:00 p.m.)

**For further information on LHAAP-18/24, please contact:**

Dr. Rose M. Zeiler
Site Manager
Longhorn Army Ammunition Plant
P.O. Box 220
Ratcliff, Arkansas 72951

Direct No.: (479) 635-0110
E-mail address: rose.m.zeiler.civ@mail.mil

The preparation and review of a Proposed Plan is a distinct step required by CERCLA. This Proposed Plan provides background information that can be found in greater detail in the Remedial Investigation (RI) Report (2001), the Post-Screening Investigations (PSIs) (conducted in 2013-2014 and 2016), the Feasibility Study (FS) (2017), and other supporting documents that are contained in the LHAAP-18/24 Administrative Record and is publicly available in the Marshall, Texas Public Library and on the Longhorn AAP Environmental

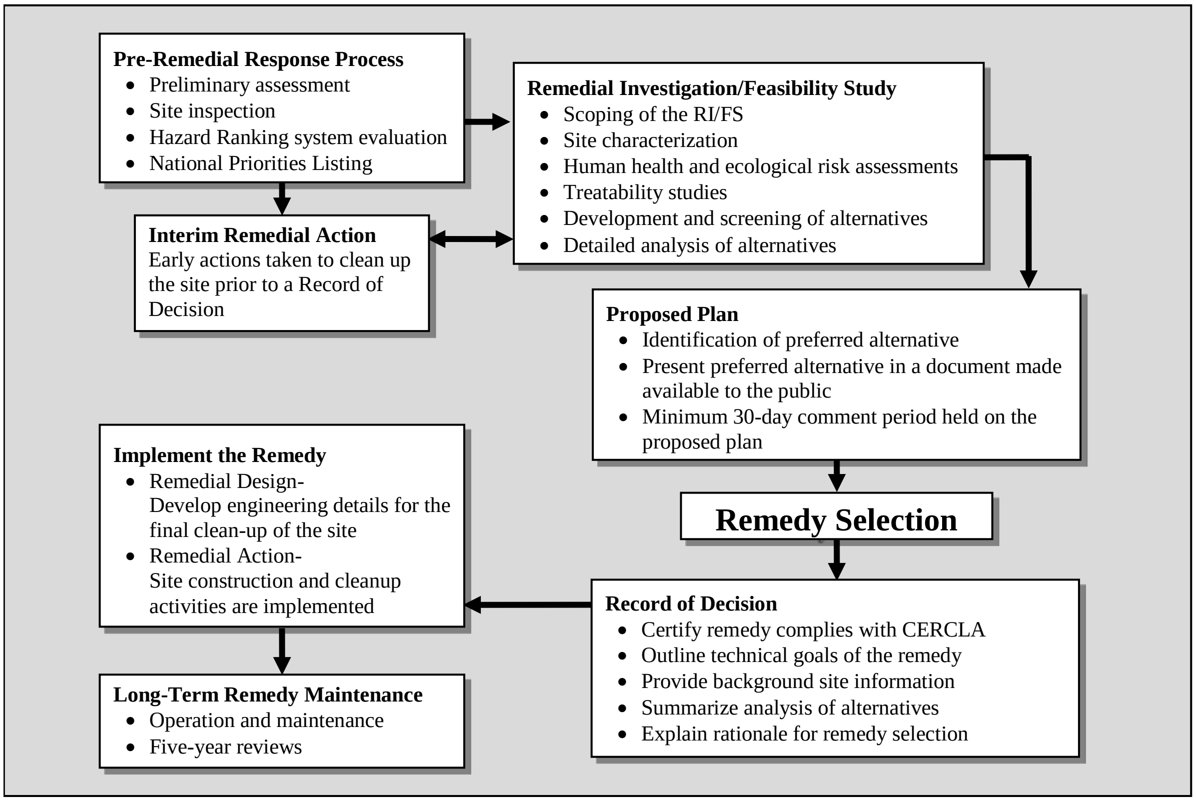


**Figure 1. CERCLA Remedial Response Process for Site Cleanup**

Restoration Program website http://www.longhornaap.com/. The project management team, including the U.S. Army, U.S. Environmental Protection Agency (USEPA), and the Texas Commission on Environmental Quality (TCEQ), encourages the public to review these documents and comment on the alternatives presented in this Proposed Plan.

The U.S. Army is acting in partnership with USEPA Region 6 (lead oversight agency) and TCEQ (support agency). As the lead agency for environmental response actions at LHAAP, the U.S. Army is charged with planning and implementing remedial actions at LHAAP. The regulatory agencies assist the U.S. Army by providing technical support, project review, project comment, and oversight in accordance with CERCLA and the NCP as well as the Federal Facility Agreement (FFA).

The Proposed Plan summarizes site characteristics, scope and role of the response action, and site risks. This is followed by a presentation of the remedial action objectives (RAOs) and a summary of remedial alternatives for LHAAP-18/24. Finally, an evaluation of alternatives and a summary of the preferred alternative are presented.

## SITE BACKGROUND

LHAAP is located in central-east Texas in the northeastern corner of Harrison County (**Figure 2**). The installation occupies approximately 1,300 of its former 8,416 acres between State Highway 43 at Karnack, Texas, and the western shore of Caddo Lake. The nearest cities are Marshall, Texas, approximately 14 miles

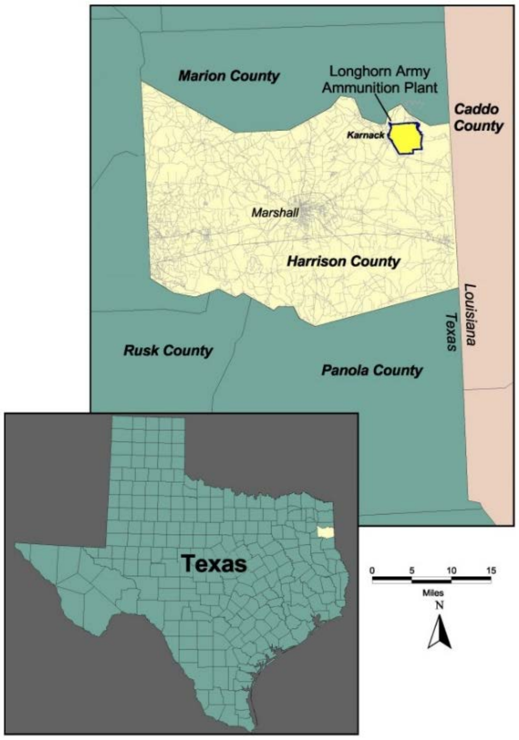


**Figure 2. Location of the Longhorn Army Ammunition Plant, Harrison County, Texas**

to the southwest, and Shreveport, Louisiana, approximately 40 miles to the southeast. Caddo Lake, a large freshwater lake situated on the Texas-Louisiana border, bounds LHAAP to the north and east (AECOM, 2017).

The U.S Army has transferred over 7,100 acres to the U.S. Fish and Wildlife Service (USFWS) for management as the Caddo Lake National Wildlife Refuge.

The property transfer process is continuing as responses are completed at individual sites. The local Restoration Advisory Board (RAB) has been kept informed of previous investigations at this site through quarterly meetings. Additionally, the administrative record is updated quarterly and is available at the local public library.

Due to releases of chemicals from facility operations, LHAAP was placed on the Superfund National Priorities List (NPL) on August 9, 1990. Activities to remediate contamination associated with the listing of LHAAP as a Superfund site began in 1990. The U.S. Army, the USEPA, and the Texas Water Commission (currently known as the TCEQ) entered into a CERCLA Section 120 FFA for remedial activities at LHAAP. The FFA became effective December 30, 1991. LHAAP operated until 1997 when it was placed on inactive status and classified by the U.S. Army Armament, Munitions, and Chemical Command as excess property. LHAAP-18/24 is an NPL site and addressed in the FFA.

LHAAP-18/24, known as the Burning Ground No. 3 (18) and Unlined Evaporation Pond (UEP) (24), is a 34.5 acre fenced, cleared area (containment area) located in the southeastern section of LHAAP (**Figure 3**). The area was used for the treatment, storage, and disposal of solid and liquid explosive, pyrotechnic, and combustible solvent waste by open burning/open detonation, incineration, evaporation, and burial (Jacobs, 2001).

LHAAP-18 Burning Ground No. 3 operated between 1955 and 1998. Historical waste management units within LHAAP-18 included open burn pits, stockpiles of solvent-soaked sawdust, and an air curtain destructor (ACD). The LHAAP- 24 UEP was used to collect water from the washout of rocket motor casings and process waste sumps from 1963 to 1984. A groundwater extraction system incorporating approximately 5,000 feet of interceptor-collection trenches (ICTs) and a groundwater treatment plant (GWTP) was installed in 1997 to control the migration of contaminated groundwater (AECOM, 2016). The area within the ICTs is considered the containment area (**Figure 3**).

Numerous investigations have been conducted at the site since 1976. The UEP was closed in 1986 with the removal of sludge and capping the impoundment. The

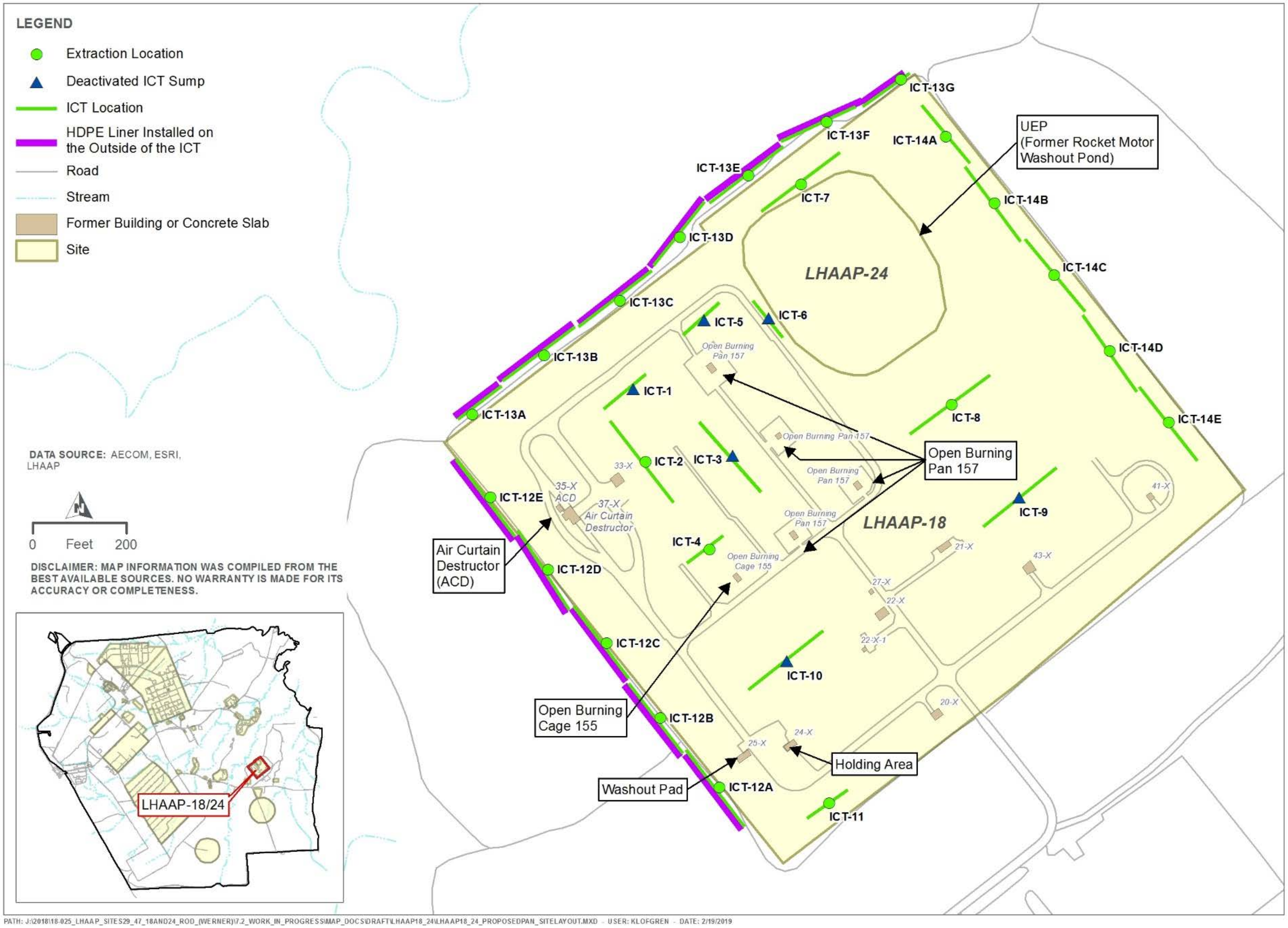


**Figure 3. LHAAP-18/24 Layout**

majority of impacts to the soil (i.e., source areas) were remediated during the 1997 LHAAP-18/24 Interim Remedial Action (IRA) where approximately 32,000 cubic yards of soil was removed (AECOM, 2017). The collective investigation results have identified impacts to soil, Shallow Zone groundwater, and underlying Wilcox Formation groundwater.

## SITE CHARACTERISTICS

LHAAP-18/24 is a cleared area within a heavily wooded section of LHAAP. The area is vegetated primarily with grass and has asphalt-paved roads. It is situated on a natural topographic high slightly west of the crest of a small topographic divide between Harrison Bayou and Saunders Branch. Topography of the site has been altered by operations over the past 35 years. The burning ground area is mostly level with more relief near the western corner and near the northern corner that contains the mounded surface of the former UEP. There are no surface water bodies or watercourses running through LHAAP-18/24. Surface drainage occurs in all directions, but flow is generally directed to the north and west by both natural and manmade ditches and drainage swales towards Harrison Bayou. Harrison Bayou drains into Caddo Lake which is located approximately 2.5-miles northeast of LHAAP-18/24 (Jacobs, 2001).

Surficial soils at LHAAP-18/24 consist of sandy silty clays and clays underlain by sandy silt to silty sand. Soil borings completed near the UEP indicate that it was constructed within these silty clayey surficial soils. Saturated sandy silt to silty sand underlying surficial clayey soil comprises the Shallow Zone groundwater. The shallow saturated zone ranges in thickness from 10-to 20-feet thick. A semi-confining clay layer is encountered below the Upper Zone. This clay layer tends to act as an aquitard between the Shallow Zone and underlying Wilcox Formation saturated zone. This semi-confining clay layer varies approximately 5-to 15-feet thick and appears to be continuous beneath the site with the exception of the west corner of the site near the area of the ACD and the northwest corner or area, outside of containment area, between LHAAP-18/24 and Harrison Bayou (Jacobs, 2001). The Wilcox Formation saturated zone varies from 10-to 35-feet thick and is underlain by a layer of clay interbedded with sand lenses that extend to the top of the Midway Formation.

Groundwater in the Shallow Zone flows radially outward in a complex pattern from the site. Shallow groundwater flow in the northwest area of the site is towards Harrison Bayou. The ICTs installed in 1997 are designed to prevent discharge of groundwater from LHAAP-18/24 to surface water (AECOM, 2016). Groundwater flow in the Wilcox Formation indicates that the gradient and direction of flow in the northern portion of the site to be similar to the Shallow Zone toward Harrison Bayou. The groundwater flow pattern and gradient direction in the Wilcox Formation prior to installation of the groundwater extraction system was similar to what is observed today (AECOM, 2017).

### *Soil Summary*

Investigations identified remaining vadose zone contaminant source areas and include the areas immediately to the west and south of the former ACD, which were not excavated as part of the IRA, and in areas immediately to the south, west and beneath the former UEP.

Analysis of the data indicated the majority of chemicals of concern (COCs) in the soil of these areas do not constitute source areas because either 1) the soil was identified to be present within the groundwater zone, such as to the west of the ACD and 2) data indicate the soil concentration decreases with depth and does not constitute a source, such as to the south of the ACD.

The 2016 PSI study focused on the southern area to determine the extent of perchlorate contamination primarily in the Shallow Zone. For the unsaturated soil samples, the results were less than the GWP-Ind (groundwater protection – industrial use) MSC (medium-specific concentration) values. For the saturated soil samples, there were two samples with detections above the GWP-Ind MSC values. Both samples were collected from the Wilcox clay in the southern corner of the site just outside of the containment area. Analysis of soil samples collected in 2013 and 2014 indicated the potential presence of residual dense non-aqueous phase liquid (DNAPL) in the saturated shallow zone at the UEP and ACD. Dissolution of residual DNAPL trichloroethylene (TCE) and methylene chloride from the UEP and ACD areas is considered to be a continuing groundwater contaminant source. The extent of DNAPL in the UEP area is approximately 35,500 square feet and the extent of DNAPL in the ACD area is approximately 5,000 square feet.

### *Groundwater Summary*

COCs were detected in monitoring wells within the Shallow Zone and Wilcox Formation. TCE, methylene chloride, and perchlorate present the vast majority of the human health risk in groundwater (**Figures 4** and **5**). The concentrations of TCE and methylene chloride in some portions of the site are sufficiently high to indicate the possible presence of DNAPL within the saturated zone. Occurrences of other volatile organic compounds (VOCs) and metals concentrations in groundwater are intermittent and their distribution is generally not contiguous across the site.

Three areas with high perchlorate concentrations were identified in the Shallow Zone wells. These areas include the area to the east of the former UEP (outside containment), in the vicinity of the former ACD, and the area southwest of the site where washout pads and sumps were operated at Building 24-x and 25-x. Perchlorate was detected at high concentrations in several Wilcox Formation wells including the area on the north side of the UEP, west of the former ACD, and south corner of the site.

The horizontal extent of TCE contamination in shallow groundwater covers the entire containment area and extends to areas southwest, northwest, and northeast outside of the containment area. The highest TCE concentrations in the shallow zone are found south of the UEP and west of the ACD. Within the Wilcox water-bearing zone, the highest TCE concentrations are found north and south of the UEP, west of the ACD and to the south near Burning Cage 155.

High concentrations of methylene chloride in the shallow and Wilcox water-bearing zones reside in two areas at the site and include the area southeast of the former UEP and west of the former ACD.

1,4-Dioxane is primarily located to the north of the ACD area in the shallow and Wilcox water-bearing zones.

## SCOPE AND ROLE OF THE PROPOSED ACTION

The scope and role of the action discussed in this Proposed Plan includes all the remedial actions planned for this site. The preferred remedial action at LHAAP-18/24 will prevent potential risks associated with exposure to contaminated soil and groundwater in both the Shallow

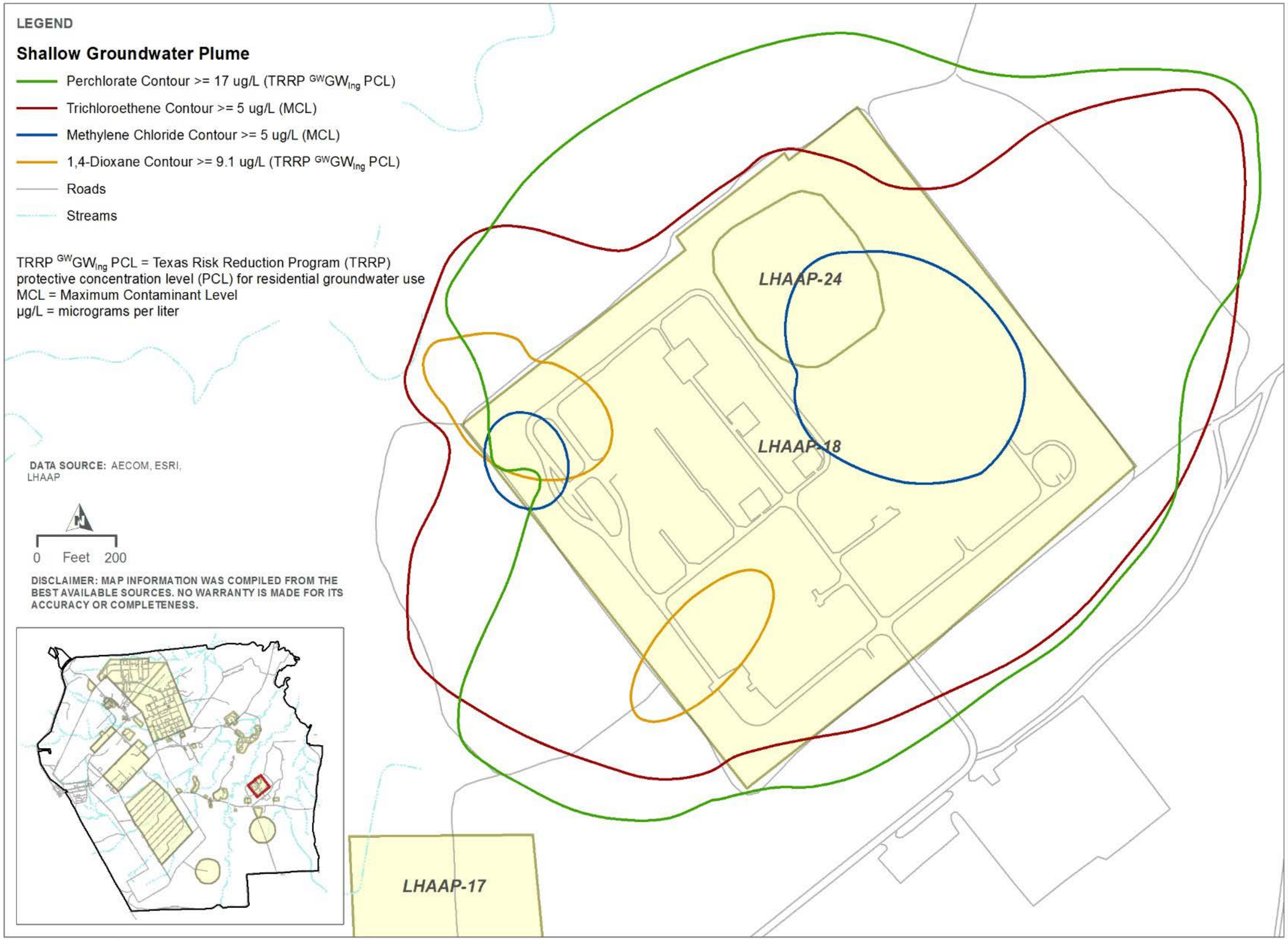


**Figure 4. LHAAP-18/24 Shallow Zone Groundwater Contamination**

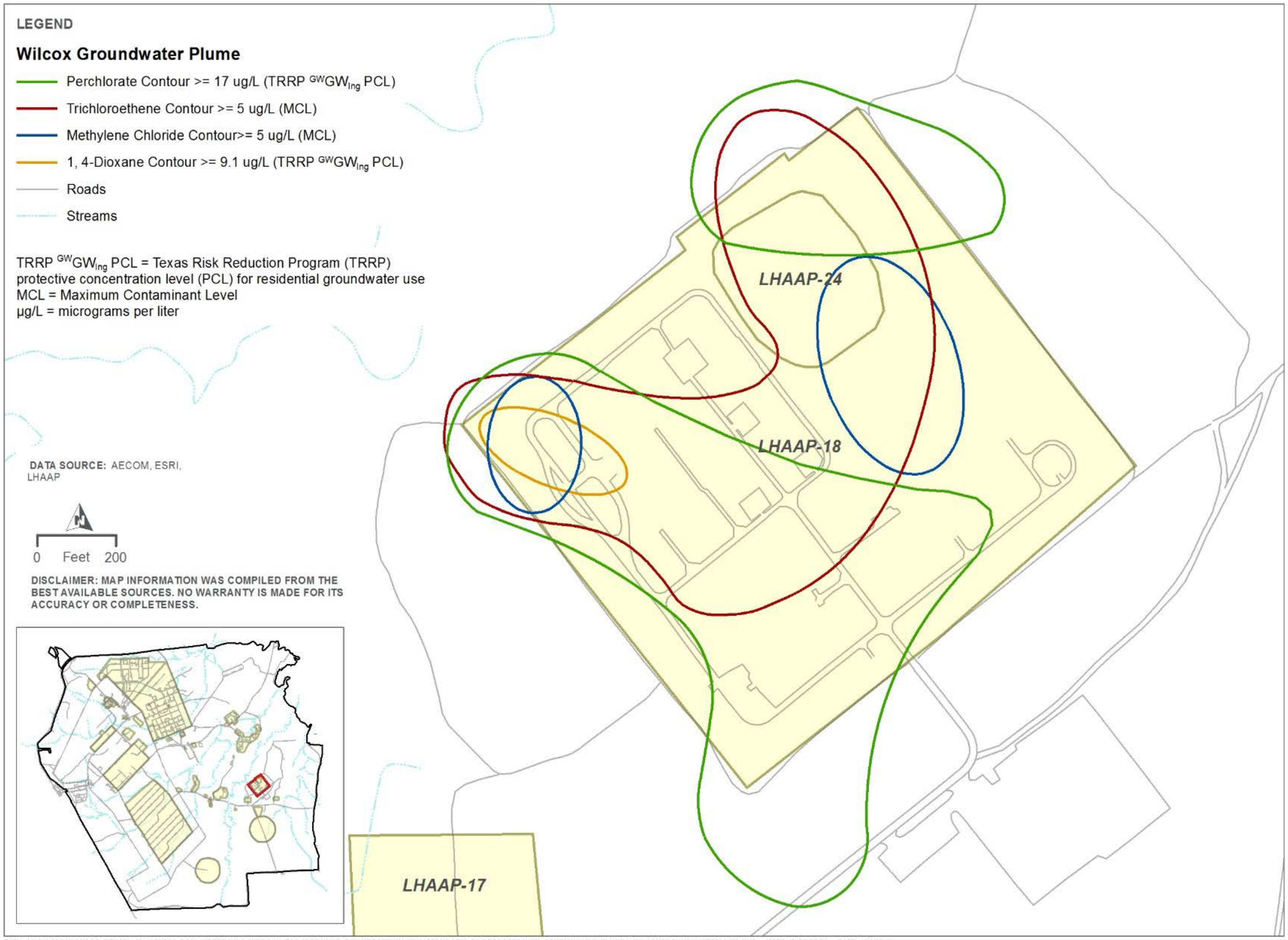


**Figure 5. LHAAP-18/24 Wilcox Formation Groundwater Contamination**

Zone and Wilcox Formation and also prevents contaminated groundwater from migrating and impacting surface water. Through the use of treatment technologies, this response will permanently reduce the toxicity, mobility, and volume of source materials that constitute the principal threat wastes at the site.

Groundwater at LHAAP is not currently being used as drinking water, nor is it anticipated to be used in the future based on its reasonably anticipated use as a national wildlife refuge. However, when establishing the RAOs for this response action, the U.S. Army has considered the NCP's expectation to return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The U.S. Army has also considered the State of Texas designation of all groundwater as potential drinking water, unless otherwise classified, consistent with Texas Administrative Code, Title 30, §335.563 (h)(1). The Army intends to return the contaminated shallow and Wilcox Formation groundwater zones at LHAAP-18/24 to its potential beneficial uses, which is considered to be the attainment of Safe Drinking Water Act Maximum Contaminant Levels (MCLs) to the extent practicable, and consistent with 40 CFR §300.430(e)(2) (i)(B&C). If an MCL is not available for a chemical, the Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Level (PCL) for residential groundwater use ($^{GW}GW_{Ing}$) will be used. If return to potential beneficial use is not practicable, the NCP expectation is to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction.

The preferred final remedial action at LHAAP-18/24 will prevent potential exposure risks associated with the contaminated groundwater, and demonstrate through groundwater and surface water monitoring activities that the nearby surface water body, Harrison Bayou, is protected from exceedances of cleanup levels. Groundwater monitoring will also verify that contaminant levels are being reduced. LUCs that restrict groundwater use will be maintained until COC levels in soil and groundwater allow for unrestricted use and unlimited exposure. The thermal treatment of residual DNAPL source areas will positively impact groundwater by eliminating the potential for the continued dissolution of COCs to groundwater. The removal of source soils will positively impact groundwater by eliminating the potential for the leaching of contaminants from the soil into groundwater.

## SUMMARY OF SITE RISKS

Results of the Baseline Human Health and Screening Ecological Risk Assessment (BHHRA, 40 CFR 300.430(e)) determined the primary environmental issue at LHAAP-18/24 is contaminated groundwater posing an unacceptable risk or hazard to the hypothetical future maintenance worker under an industrial scenario.

### *Groundwater*

COCs in the Shallow Zone groundwater include the following:

***VOCs***

- methylene chloride
- TCE
- cis-1,2-dichloroethylene (DCE)
- tetrachloroethylene (PCE)
- benzene
- 1,1,2-trichloroethane (TCA)
- vinyl chloride
- bromodichloromethane
- 1,3,5-trinitrobenzene
- 1,4-dioxane

***Metals***

- arsenic
- barium
- chromium
- cobalt
- nickel

***Anions***

- perchlorate

In the underlying Wilcox Formation, COCs in groundwater include the following:

***VOCs***

- methylene chloride
- TCE
- cis 1,2-DCE
- PCE
- benzene
- 1,1,2-TCA
- 1,1,1,2-tetrachloroethane
- vinyl chloride
- bromodichloromethane
- 1,3,5-trinitrobenzene
- 1,4-dioxane

***Metals***

- arsenic
- barium
- cobalt

***Anions***

- perchlorate

The proposed cleanup level is the MCL, where it exists (42 U.S.C. §9621(d)(2)(A)). Where an MCL has not been promulgated, the TRRP Tier 1 PCL for residential groundwater use (TRRP $^{GW}GW_{Ing}$ PCL) will be used. The maximum detected concentrations of the COCs from the June 2016 sampling event and the MCLs or TRRP $^{GW}GW_{Ing}$ PCL for the Shallow Zone and the Wilcox Formation are presented in **Tables 1** and **2**, respectively. Bromodichloromethane, 1,3,5-trinitrobenzene, arsenic, and cobalt have been retained on a provisional basis, because the concentrations above the cleanup level are only detected sporadically (cobalt), no recent results are

**Table 1. Shallow Zone Groundwater Chemicals of Concern**

| Chemical | Maximum Concentration (µg/L) | MCL (µg/L) |
|---|---|---|
| Methylene chloride | 21,300 | 5 |
| Trichloroethylene | 17,100 | 5 |
| cis-1,2-Dichloroethene* | 43,600 | 70 |
| Tetrachloroethylene | 85.1 | 5 |
| Benzene | <62.6 | 5 |
| 1,1,2-Trichloroethane | <50 | 5 |
| Vinyl chloride* | 256 | 2 |
| Arsenic | 16.1 | 10 |
| Barium | 10,300 | 2,000 |
| Chromium | 4,620 | 100 |
| | | TRRP $^{GW}GW_{Ing}$ PCL** (µg/L) |
| Bromodichloromethane | <125 | 15 |
| 1,3,5-trinitrobenzene | No recent data | 730 |
| 1,4-Dioxane | 220 | 9.1 |
| Cobalt | 355 | 240 |
| Nickel | 14,300 | 490 |
| Perchlorate | 82,900 | 17 |

Notes:
* trichloroethylene daughter products
**TRRP $^{GW}GW_{Ing}$ PCL from April 2018, https://www.tceq.texas.gov/remediation/trrp/trrppcls.html
µg/L micrograms per liter
MCL maximum contaminant level
NA Not Available
Samples collected June 2016 (AECOM, 2016b)

**Table 2. Wilcox Formation Groundwater Chemicals of Concern**

| Chemical | Maximum Concentration (µg/L) | MCL (µg/L) |
|---|---|---|
| Methylene chloride | 746 | 5 |
| Trichloroethylene | 15,900 | 5 |
| cis-1,2-Dichloroethene* | 2,600 | 70 |
| Benzene | 6.13 | 5 |
| 1,1,2-Trichloroethane | 0.858 | 5 |
| Vinyl chloride* | 8.97 | 2 |
| Arsenic | 17.3 | 10 |
| Barium | 10,300 | 2,000 |
| | | TRRP $^{GW}GW_{Ing}$ PCL** (µg/L) |
| Bromodichloromethane | <40 | 15 |
| 1,1,1,2-Tetrachloroethane | <50 | 35 |
| 1,3,5-trinitrobenzene | No recent data | 730 |
| 1,4-Dioxane | 412 | 9.1 |
| Cobalt | 9.64 | 240 |
| Perchlorate | 229,000 | 17 |

Notes:
* trichloroethylene daughter products
**TRRP $^{GW}GW_{Ing}$ PCL from April 2018, https://www.tceq.texas.gov/remediation/trrp/trrppcls.html
µg/L micrograms per liter
MCL maximum contaminant level
NA Not Available
Samples collected June 2016 (AECOM, 2016b)

available (1,3,5-trinitrobenzene), detection limits for recent results were above the cleanup levels (bromodichloromethane), or the COC is not associated with the site (arsenic).

For the hypothetical future maintenance worker's exposure to groundwater, the carcinogenic risk and non-carcinogenic hazard exceed the acceptable limits. The total carcinogenic risk was determined at $4.4 \times 10^{-1}$, with TCE and methylene chloride contributing 99.98% of the risk. The total Hazard Index (HI) was calculated at 3,200, with methylene chloride, TCE, and perchlorate contributing greater than 98% of the HI. The reason for the high cancer risk and hazard index calculated for the hypothetical maintenance worker was related to the unlikely assumption that groundwater extracted from the site would be used by the maintenance worker for showering, during which dermal and inhalation exposure to the contaminants in groundwater would occur. The Installation-Wide Baseline Ecological Risk Assessment did not identify potential risk to ecological receptors at LHAAP-18/24.

### *Soil*

For the hypothetical future maintenance worker's exposure to soil at LHAAP-18/24, the carcinogenic risk was determined to be $5.0 \times 10^{-7}$ and a non-carcinogenic hazard of 0.042; therefore, chemicals in soil do not pose unacceptable carcinogenic risk or non-carcinogenic hazard to human health. The potential soil-to-groundwater pathway was evaluated for TCE, methylene chloride (MC), PCE and perchlorate. The concentrations of these chemicals were compared to their TCEQ soil MSCs for industrial use based on groundwater protection (GWP-Ind MSC), which are more stringent than the soil MSCs for industrial use based on inhalation, ingestion, and dermal contact (TCEQ, 2006). Because the GWP-Ind MSC values are more stringent, they are the proposed soil cleanup levels. The maximum detected concentrations of the COCs in unsaturated soil and GWP-Ind MSC (proposed as the cleanup levels) are presented in **Table 3**.

**Table 3. Soil Chemicals of Concern**

| Chemical | Location and Depth (feet bgs) | Maximum Concentration (mg/kg) | GWP-Ind MSC (mg/kg) |
|---|---|---|---|
| Methylene Chloride[1] | 18CPTUEP05[1], 24-25 | 3.42 | 0.5 |
| Trichloroethylene | 18CPT21[2], 16-17 | 11.6 | 0.5 |
| Perchlorate | 18CPTBB02[1], 4.5-5.5 | 18.7 | 7.2 |
| Tetrachloroethene | 18CPT21[2], 16-17 | 71.3 | 0.5 |

Notes:
[1] Sample collected 5/2014
[2] Sample collected 3/2013
bgs below ground surface
mg/kg milligrams per kilogram
GWP-Ind MSC Texas Commission on Environmental Quality soil medium-specific concentration (MSC) for industrial use based on groundwater protection

It is the current judgment of the U.S. Army that the Preferred Alternative identified in this Proposed Plan, or one of the other active measures considered in the Proposed Plan, is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

## REMEDIAL ACTION OBJECTIVES

The future use of the entire LHAAP facility is as a National Wildlife Refuge. The RAOs for LHAAP-18/24, which address contamination associated with the media at the site and take into account the future uses of LHAAP streams, land, and groundwater are as follows:

***Groundwater***

- Protect human health by preventing human exposure to the groundwater contaminated with COCs,
- Protect human health and the environment by preventing groundwater contaminated with COCs from migrating into nearby surface water,
- Return groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site (40 CFR 300.430(a)((1)(iii)(F)).

***Soil***

- Protect human health and the environment by preventing the migration of contaminants to groundwater from potential sources in the soil.

## SUMMARY OF REMEDIAL ALTERNATIVES

The Revised FS identified and screened remedial technologies and associated process options that may be appropriate for satisfying the RAOs for LHAAP-18/24 with respect to effectiveness, implementability, and cost. All costs presented herein are based on 30 years of implementation only. For alternatives taking longer than 30 years to achieve RAOs, costs would be considerably higher. The following remedial alternatives were developed from the retained remedial technologies carried forward after the initial screening:

- **Alternative 1 –** No Action, as required by the NCP.
- **Alternative 2 –** Enhanced Groundwater Extraction and Ex-Situ Treatment, LUCs in the Shallow Zone and Wilcox Formation, EISB Inside & Outside the Containment Area in the Shallow Zone and in the Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal.
- **Alternative 3 –** Groundwater Extraction and Treatment, Monitored Natural Attenuation (MNA) Outside the Containment Area in the Shallow Zone and in Wilcox Formation, LUCs in the Shallow Zone and Wilcox Formation, and Containment.
- **Alternative 4 –** Enhanced Groundwater Extraction and Treatment, LUCs in the Shallow Zone and Wilcox Formation, EISB Inside & Outside the Containment Area in the Shallow Zone and in the Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, and Surfactant Enhanced DNAPL Removal.
- **Alternative 5 –** Enhanced Groundwater Extraction and Treatment, LUCs in the Shallow Zone and Wilcox Formation, EISB Inside and Outside the Containment Area in the Shallow Zone and in the Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, Thermal DNAPL Removal.
- **Alternative 6 –** Enhanced Groundwater Extraction and Treatment, LUCs in the Shallow Zone and Wilcox Formation, EISB Inside and Outside the Containment Area in the Shallow Zone and in the Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, Enhanced DNAPL Remediation using Zero-Valent Iron (ZVI).

***Common Elements.*** There are a number of remedial process options that are common to many of these six remedial alternatives and are summarized in **Table 4**.

A number of process options are common to all action alternatives (Alternatives 2 through 6):

- Maintenance of the existing cap over the former UEP.
- MNA that occurs at the site to reduce and control COC concentrations in areas outside the direct influence of the containment area. MNA was evaluated and is a viable option for those areas but not as a primary remedy as additional evidence is needed for MNA to be used as a primary remedy. MNA for 1,4-dioxane has not been established at this time.
- LUCs will be implemented to support the RAOs. The U.S. Army will be responsible for implementation, maintenance, inspection, reporting, and enforcement of the LUCs. The U.S. Army intends to provide details of the LUC implementation actions in a Remedial Design (RD) document. Until cleanup levels are met in the groundwater for Alternatives 2 through 6, the LUCs will prevent human exposure to residual groundwater contamination presenting an unacceptable risk to human health by ensuring there is no withdrawal or use of groundwater beneath the site for anything other than treatment, environmental monitoring, or testing.

  The LUC objectives include maintaining the integrity of any current or future remedial or monitoring systems, and preventing the use of groundwater contaminated above cleanup levels as a potable water source.

  - LUC to restrict land use to non-residential use until it is demonstrated that the COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.
  - LUC prohibiting potable use of groundwater above cleanup levels until it is demonstrated that the COCs are at levels that allow for unlimited use and unrestricted exposure.
  - LUC to maintain the remedial and monitoring systems associated with the groundwater remedies until these components of the remedy are no longer needed to achieve cleanup levels, and cleanup levels have been achieved.

In addition, the Texas Department of Licensing and Regulation will be requested to notify well drillers of groundwater restrictions. The recordation of the LUCs with the Harrison County Courthouse will be completed and will include a map showing the areas of groundwater restriction at the site. These restrictions will prohibit or restrict property uses that may result in exposure to the contaminated groundwater.

In order to transfer this property (LHAAP-18/24), an environmental condition of property (ECP) document will be prepared and the Environmental Protection Provisions from the ECP will be attached to the letter of transfer. The ECP will include LUCs for groundwater soil, and the remedial and monitoring system as part of the Environmental Protection Provisions. The property will be transferred subject to the LUCs identified in the ECP. These restrictions will prohibit or restrict

**Table 4. Common Remedial Process Options for Remedial Alternatives**

| Media | Remedial Process Option | Remedial Alternative | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Groundwater | Continue operation of the current or a new groundwater extraction and treatment system with contingent 1,4-dioxane treatment component. | -- | X | X | X | X | X |
| | Slurry wall groundwater containment; improve ground surface to promote runoff. | -- | | X | | | |
| | EISB inside containment in Shallow Zone and Wilcox Formation, and EISB outside containment. | -- | X | | X | X | X |
| | MNA and LUCs until cleanup levels are met. | -- | X | X | X | X | X |
| Soil (vadose zone) | Maintain cap over former UEP. | -- | X | X | X | X | X |
| | Cap additional area to reduce infiltration. | -- | | X | | | |
| | Excavate source areas. | -- | X | | X | X | X |
| | Excavate soil under UEP. | -- | X | | X | X | X |
| Soil (residual DNAPL in saturated zone) | DNAPL removal via extraction, surfactant flushing, ZVI, or ERH. | -- | X | | X | X | X |
| | EISB. | -- | | | X | X | X |

property uses that may result in exposure to the contaminated groundwater and any residual soil contamination greater than levels that allow for unlimited use and unrestricted exposure. Although the U.S. Army may later pass these procedural responsibilities to the transferee by property transfer agreement, the U.S. Army will retain ultimate responsibility for remedy integrity.

- Operation of the existing GWTP and associated groundwater extraction system. The intensity and duration of continued use varies within the alternatives.

***Alternative 1 – No Action.***

*Estimated Capital Cost:* $0
*Estimated Annual Operation and Maintenance (O&M) Cost:* $0
*Estimated Present Worth Cost:* $0
*Estimated Time to Achieve RAOs:* Not Achievable

Contaminated groundwater and source areas in the saturated and unsaturated soil would be left in place with no remedial action or additional measures to prevent exposure to the COCs or to prevent migration. The No Action alternative serves as a baseline for comparison with other alternatives as required by the NCP (40 CFR 300.430(e)). The No Action alternative does not meet the RAOs.

***Alternative 2 – Enhanced Groundwater Extraction and Ex-Situ Treatment, Land Use Controls (LUCs), Enhanced In-Situ Bioremediation (EISB) Inside & Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal.***

*Estimated Capital Cost:* $14.56M
*Estimated Annual Operation and Maintenance (O&M) Cost:* $19.6
*Estimated Present Worth Cost:* $34.16M
*Estimated Time to Achieve RAOs:* Several hundred years

Under Alternative 2, the existing groundwater extraction and treatment system would continue operating for contaminant removal, hydraulic control, and groundwater treatment. Previously inactivated interception collection trenches (ICT3 and ICT9) would potentially be phased in for reactivation to remove more contaminant mass from groundwater. Saturated soil contaminated with VOCs or perchlorate at high concentrations that may be acting as a source of groundwater contamination (one area in the UEP vicinity and another area in the ACD vicinity) would be remediated by groundwater extraction using vertical extraction wells. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure. Maintenance of the UEP cover will continue. EISB would be conducted in Shallow Zone contaminated areas inside and outside the containment area and in three or more areas in the Wilcox Formation. Unsaturated soil in two areas south of the UEP and two areas to the west of the UEP would be excavated and disposed off-site. The cost estimate for two soil areas beneath the UEP will be developed but the actual implementation would be deferred to year 6 of remedy implementation at the earliest. In the interim, maintenance of the UEP cap will continue. Continued operation of current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane is included in this alternative.

This alternative is estimated to take between 300 and 500 years to achieve RAOs. LUCs would be implemented along with maintenance of the UEP cover to prevent human exposure to contaminated groundwater.

***Alternative 3 – Groundwater Extraction and Treatment, Containment (slurry wall), MNA outside the containment and in Wilcox Formation, and LUCs.***

*Estimated Capital Cost:* $6.41M
*Estimated Annual Operation and Maintenance (O&M) Cost:* $12.24M
*Estimated Present Worth Cost:* $18.65M
*Estimated Time to Achieve RAOs:* Several hundred years

Alternative 3 would include the installation of a slurry wall to contain contaminated groundwater in the Shallow Zone; additional soil cover would be added to portions of the site and the drainage ditches would be improved to promote runoff and reduce infiltration. The slurry wall would be tied into the clay layer, where present, that separates the Shallow Zone from the Wilcox aquifer. Where the clay layer is not present, the slurry wall would be installed to a depth just below the bottom depth of Harrison Bayou to the north of the containment. The existing groundwater extraction system would be used as needed to maintain hydraulic control inside the slurry wall, and would be ramped down gradually to an approximate 65% extraction rate (actual rate that would be required to achieve an inward and upward gradient would be determined with a 2-year hydraulic evaluation). MNA would ensure that groundwater contamination remains localized for the areas outside the slurry wall and within the Wilcox Formation. This alternative would take a very long time (several hundred years) to achieve RAOs. Continued operation of the current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane is included in this alternative. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure. Maintenance of the UEP cap will continue.

***Alternative 4 – Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside & Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, and Surfactant Enhanced DNAPL Removal.***

*Estimated Capital Cost:* $13.11M

*Estimated Annual Operation and Maintenance (O&M) Cost:* $19.39M
*Estimated Present Worth Cost:* $32.5M
*Estimated Time to Achieve RAOs:* 30+ years

Alternative 4 would employ surfactant flushing technology to treat saturated soil contaminated with VOCs or perchlorate at high concentrations in the vicinity of the UEP and ACD. EISB will also be applied to these areas after completion of surfactant flushing as a polishing step because surfactant flushing effectiveness might be hindered by low permeability zones and to remove perchlorate that has not been treated via surfactant flushing. EISB would be conducted in Shallow Zone contaminated areas inside and outside the containment area and in three or more areas in the Wilcox Formation. Unsaturated soil in two areas south of the UEP, two areas to the west of the UEP, and two areas beneath the UEP would be excavated and disposed off-site. The actual implementation of the soil excavation would be deferred to year 6 of remedy implementation at the earliest. Maintenance of the UEP cap would continue. The groundwater extraction system in its enhanced form (with potential phased reactivation of ICT 3 and ICT 9) would continue operating to maintain hydraulic control and remove remaining Shallow Zone contaminants within the containment area. Continued operation of the current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane is included in this alternative. This alternative would achieve site RAOs more quickly than Alternatives 2 and 3, but is expected to exceed 30 years. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure. Maintenance of the UEP cover will continue.

***Alternative 5 – Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside and Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, Thermal DNAPL Removal.***

*Estimated Capital Cost:* $19.52M
*Estimated Annual Operation and Maintenance (O&M) Cost:* $13.15M
*Estimated Present Worth Cost:* $32.67M
*Estimated Time to Achieve RAOs:* 20 years

Alternative 5 is the same as Alternative 4 with the exception that thermal treatment is applied at the residual DNAPL source areas of the UEP and ACD instead of surfactant flushing. Under Alternative 5, two in-situ thermal desorption (ISTD) technologies (Electrical Resistance Heating [ERH] or Thermal Conduction Heating [TCH]) may be considered to treat the high concentration dissolved VOCs and DNAPL in the Shallow Zone and Wilcox groundwater. While the technology is more expensive, it is very effective in low permeability zones where the majority of the residual DNAPL resides. A removal rate of 99.9% is expected. EISB would be applied to the thermally-treated areas as a polishing step after thermal treatment is completed. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure. Maintenance of the UEP cap will continue. It is estimated that this alternative allows achievement of the RAOs within 20 years.

***Alternative 6 – Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside and Outside Containment Area and in Wilcox Formation, Unsaturated***

***Soil Excavation and Off-Site Disposal, Enhanced DNAPL Remediation using Zero-Valent Iron (ZVI).***

*Estimated Capital Cost:* $102.23M
*Estimated Annual Operation and Maintenance (O&M) Cost:* $19.39M
*Estimated Present Worth Cost:* $121.62M
*Estimated Time to Achieve RAOs:* 30 years

Alternative 6 is the same as Alternative 5 but instead of using in-situ thermal remediation, ZVI for treatment of residual DNAPL source areas would be used. Uniform distribution of ZVI in low permeability zones may not be possible due to subsurface heterogeneity and therefore, effective remediation of these areas by ZVI may not be effective. Hence, EISB would be applied to these areas after ZVI remediation is completed as a polishing step. It is estimated that 70% to 80% reduction in CoCs would occur after each injection of ZVI with two injections planned for the site. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure. Maintenance of the UEP cap will continue. With application of EISB after the ZVI, it is estimated that this alternative allows achievement of the RAOs within 30 years.

## EVALUATION OF ALTERNATIVES

Nine criteria identified in the NCP, 40 CFR §300.430(e)(9)(iii), are used to evaluate the different remediation alternatives individually and against each other in order to select a remedy. This section profiles the relative performance of each alternative against the nine criteria, noting how it compares to the other alternatives under consideration. The nine evaluation criteria are discussed below. The "Detailed Analysis of Alternatives" can be found in the Revised FS for LHAAP-18/24 (AECOM, 2017).

### 1. Overall Protection of Human Health and the Environment

The six alternatives provide varying levels of human health protection. Alternative 1, No Action, does not achieve the RAOs and provides the least protection of all the alternatives; it provides no reduction in risks to human health and the environment because no measures would be implemented to eliminate potential exposure pathways for human exposure to the groundwater contamination or potential migration of COCs from groundwater to surface water.

All five action alternatives protect human health and the environment. The action alternatives implement LUCs to prevent access to the Shallow Zone and Wilcox Formation groundwater until cleanup levels are achieved. MNA will continue to ensure the plume originating within the containment area is stable and contained. Operation of the GWTP will continue to ensure the plume originating within the containment area is stable and contained. Alternative 3, which relies the most heavily on containment and LUCs, does not provide the same degree of contaminant removal or treatment in groundwater as the other alternatives, but would be protective of human health because the LUCs would prevent human access to the contaminated groundwater in the Shallow Zone and Wilcox Formation. Alternative 3 prevents migration of COCs from groundwater outside containment to surface water, but does not prevent continued leaching from soil into the groundwater. The GWTP would provide hydraulic control. Alternatives 2, 4, 5, and 6 provide a similar level of overall protection and can eventually achieve the cleanup levels for the groundwater COCs due to active remediation and continued operation of the groundwater treatment system for contaminant removal; however, the duration to achieve the cleanup levels vary. Remedial time frames span from hundreds of years for Alternatives 2 and 3, 30 years for Alternatives 4 and 6, and 20 years for Alternative 5.

### 2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

The Applicable or Relevant and Appropriate Requirements can be found in the FS for LHAAP-18/24 (AECOM, 2017).

Alternative 1 does not comply with chemical-specific ARARs for groundwater, unsaturated soils, or secondary source within the saturated soil because no remedial measures would be implemented.

Alternative 3 is not expected to return groundwater concentrations within the slurry wall to less than the cleanup levels for several hundred years.

Alternatives 2, 4, 5, and 6 comply with the chemical-specific ARARs for groundwater, unsaturated soil, and secondary groundwater source (residual DNAPL) because they prevent exposure to groundwater that exceeds ARARs and would eventually return groundwater and soil concentrations to less than cleanup levels.

All of the action alternatives would comply with the action-specific ARARs.

### 3. Long-Term Effectiveness and Permanence

Alternative 1 would not be effective or permanent in the long term because no contaminant removal or treatment would take place and no measures would be implemented to control exposure to risks posed by contaminated groundwater or the potential for contaminated groundwater to migrate to Harrison Bayou.

Alternative 2 offers a moderate degree of long-term effectiveness through operation of an enhanced groundwater extraction (vertical extraction wells) and treatment system, EISB inside and outside the containment area and in the Wilcox Formation, in combination with unsaturated soil removal, residual DNAPL source removal, and LUC implementation, which would minimize the potential risk posed by the contaminated groundwater. Reduction of the residual DNAPL source with groundwater extraction is not highly effective and therefore, the potential for significant residual risk would remain.

Alternative 3 offers a degree of long-term effectiveness through physical containment of contaminated groundwater using a slurry wall and gradient control by pumping, combined with MNA to monitor effectiveness and LUCs to prevent groundwater use. Alternative 3 is designed to contain contaminated groundwater in place in perpetuity. While the exposure RAO would be satisfied by this alternative, the RAO for groundwater restoration would not be met within the slurry wall and would require operation of the GWTP for several hundred years. Therefore, the groundwater restoration RAO would need to be waived for this area.

Alternative 4 offers a higher degree of long-term effectiveness compared to Alternatives 2 and 3 through surfactant flushing of residual DNAPL, EISB of groundwater inside and outside the containment and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the Shallow Zone, unsaturated soil excavation, enhanced groundwater extraction and treatment system, and LUC implementation. Alternative 4 is likely to achieve groundwater cleanup levels in a shorter period of time than Alternative 2. However, the period of time required to attain RAOs remains long because the effectiveness of surfactant flushing of residual DNAPL is uncertain due to the difficulty in reaching into the low permeability zones.

Alternative 5 offers the highest degree of long-term effectiveness through thermal remediation of VOCs in residual DNAPL saturated soil areas in groundwater, EISB of groundwater inside and outside the containment area and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the Shallow Zone, unsaturated soil excavation, enhanced groundwater extraction and treatment system, and LUC implementation. Alternative 5 would achieve groundwater cleanup levels in a shorter period of time than Alternatives 3 or 4 because 99.9% removal of VOCs from the residual DNAPL areas is possible.

Alternative 6 also offers a high degree of long-term effectiveness through application of ZVI to the residual DNAPL saturated soil areas, EISB of groundwater inside and outside the containment and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the shallow zone, unsaturated soil excavation, enhanced groundwater extraction and treatment, and LUC implementation. Alternative 6 relies on effective distribution of injected ZVI to all impacted areas. However, the ability to distribute injected ZVI into low permeability zones with high residual DNAPL may not be effective, and achieving results comparable to the treatability study results of greater than 99% reduction of TCE and high percentage reduction of MC and perchlorate is unlikely.

Alternative 5 is expected to require the shortest duration to achieve RAOs and allow shutdown of the GWTP. Alternatives 4 and 6, while rapidly addressing COCs in residual DNAPL areas, suffer from the difficulty of distributing the injected material to low permeability zones and may not be as effective as would be expected from a treatability test results where contact between the contaminants and the material is not limiting. Alternative 2 would not achieve the RAOs within an acceptable period of time, i.e., several hundred years. Alternative 3 would require several hundred years to achieve cleanup levels within the slurry wall, and, due to the risk of containment failure, would be the least permanent remedy.

**4. Reduction of Toxicity, Mobility, or Volume through Treatment**

Alternative 1 does not employ treatment in groundwater and would not result in a reduction of toxicity, mobility, or volume of contaminants. All of the action alternatives provide some degree of reduction of toxicity, mobility or volume through treatment. Alternative 2 provides a reduction in toxicity, mobility and volume via continued operation of an enhanced groundwater extraction and treatment system but the rate of reduction expected within the residual DNAPL areas would be slow.

Alternative 3 provides mobility reduction through the installation of a slurry wall and continued hydraulic control as needed. Reduction of volume through treatment is limited to natural attenuation mechanisms of contaminants outside the slurry wall and ex situ treatment of extracted groundwater from within the containment area.

Alternative 4 provides permanent reduction in toxicity and volume of the groundwater contaminants in a shorter timeframe than Alternatives 2, and 3. This is achieved through surfactant flushing of saturated source soil to remove DNAPL that may serve as a long-term source of groundwater contamination, as well as excavation of unsaturated soil, and implementation of EISB in areas inside and outside the containment and within the Wilcox Formation. In addition to enhanced groundwater extraction, all the above technologies would result in a reduction in contaminant toxicity, mobility, and volume. However, only a partial reduction of mass of the residual DNAPL via surfactant flushing is expected to be achievable due to the difficulty of getting the surfactants to reach low permeability zones. Natural attenuation mechanisms of contamination outside the containment area would continue to act to reduce contaminant mass.

Alternative 5 provides the greatest reduction in toxicity, mobility, and volume of the groundwater contaminants compared to the other alternatives. This is achieved through thermal treatment of saturated source soil to treat DNAPL that may serve as a long-term source of groundwater contamination, excavation of unsaturated soil, and implementation of EISB in areas inside and outside the containment and within the Wilcox Formation. In addition to enhanced groundwater extraction, this technology would result in a reduction in contaminant toxicity, mobility, and volume. Natural attenuation mechanisms of contamination outside the containment area would continue to act to reduce contaminant mass.

Alternative 6 provides a high level of reduction in toxicity, mobility, and volume of the groundwater contaminants compared to the other alternatives but is expected to be less than that achieved by Alternative 5. Reduction of mass of residual DNAPL via ZVI injection is expected to be partial due to difficulty of the ZVI to effectively reach low permeability zones. Excavation of unsaturated soil and implementation of EISB in areas inside and outside the containment and within the Wilcox Formation, in addition to enhanced groundwater extraction would result in a reduction in contaminant toxicity, mobility, and volume. Natural attenuation mechanisms of contamination outside the containment area would continue to act to reduce contaminant mass.

### 5. Short-Term Effectiveness

Because Alternative 1 does not involve remedial measures, no short-term risk to workers, the community, or the environment would exist.

All of the action alternatives involve potential short-term risks to workers associated with exposure to contaminated groundwater, vapor (i.e., volatilized and extracted VOCs), from monitoring and/or operation of drilling/construction equipment.

Alternative 2 presents risks associated with drilling new extraction wells, trenching for placement of conduits, and potential exposure to contaminated groundwater or heavy equipment. Alternative 2 presents potential risks associated with soil excavation (particulate emissions, heavy equipment) and off-site disposal which represents a greater exposure potential to LHAAP-18/24 workers, a greater potential for runoff releases to the environment and the potential for offsite traffic accidents and impacts on communities between LHAAP and the disposal facility. Risks are also associated with handling of chemicals used for EISB, although these chemicals are typically food grade and not harmful. Use of application equipment can also present risks to workers.

Alternative 3 involves risks associated with operation of the heavier equipment used in slurry wall construction and with handling the bentonite slurry used in construction. Alternative 4 requires a large construction footprint and would result in disturbing a wide area along the path of construction which would have an impact on the environment. Control of run-on and run-off would be critical to prevent cross-contamination of surface water. Risks associated with subsurface utilities are another concern for slurry wall installation.

Alternative 4 involves the same risks as Alternative 2 with the additional risks associated with surfactant flushing implementation which includes potential exposure to the surfactant and extracted fluids from the subsurface which would require surface handling, storage, treatment, and disposal.

Alternative 5 presents similar risks to Alternative 2 but has additional risks associated with implementation of thermal treatment technology which requires use of high voltage equipment and results in volatilization of VOCs that requires treatment at the ground surface.

Alternative 6 presents similar risks like Alternative 2 but with additional risk associated with use and handling of ZVI.

By planning the construction, excavation, and transportation activities in accordance with industry and Occupational Safety and Health Administration (OSHA) codes and requirements, risks from contaminant exposure and construction operations would be controlled to acceptable levels. Dust control and sediment deposition into adjacent surface water bodies can be controlled during earthwork and construction activities. Erosion control measures would include surface grading; emplacement of silt fences; covering surfaces with straw, mulch, riprap, and/or geotextile fabrics. Following completion of all construction and excavation, disturbed areas would be regraded with clean backfill and revegetated with native grasses. Appropriate personal protective equipment (PPE) would be required for remediation workers. Overall risk can be mitigated by developing a health and safety plan in compliance with OSHA requirements, communicating the hazards to involved parties, and providing the know-how and tools to mitigate those hazards.

### 6. Implementability

Administratively, all the action alternatives are implementable. However, Alternative 1, No Action, would involve shutting down the groundwater extraction system, which is assumed to be administratively unacceptable to the U.S. Army and to the regulatory agencies.

The action alternatives for groundwater are all technically implementable with varying degrees of difficulty.

A potential phased reactivation of existing ICTs 3 and 9 for Alternatives 2, 4, 5, and 6 should be easy to implement as the tools and skilled resources are available. Similarly, implementation of additional extraction points for Alternative 2 should not pose any difficulties to drill the wells and connect the wells to the GWTP. EISB is specified for Alternatives 2, 4, 5, and 6. EISB has been implemented at other LHAAP sites and should not pose any difficulties to implement at LHAAP-18/24. Success of EISB was determined by conducting treatability testing and bioaugmentation at the laboratory scale. Treatability testing at the bench-scale and pilot-scale would also be required for surfactant remediation to select and optimize surfactant dose and provide proof of concept for Alternative 4 (i.e., loss of control for DNAPL migration, generation of adverse chemicals, and penetration effectiveness in low permeability zones). Thermal treatment (Alternative 5) does not require treatability testing and its implementability hinges on the availability of power to supply the electrodes with sufficient power to heat the saturated soils. Considering that power reliability has been a concern at the GWTP, this would be an important design consideration for this technology. Implementation of ZVI for Alternative 6 faces similar implementability considerations such as EISB implementation.

Alternative 3 has two significant implementation issues: 1) the slurry wall would need to key into the confining layer for the Shallow Zone, and 2) any significant discontinuities in the confining layer would need to be addressed. To mitigate these potential containment gaps, hydraulic control throughout the system would be achieved with the GWTP. For Alternative 2, 4, 5, and 6 soil excavation would also require coordination between excavation, sampling, transportation and disposal. However, because the volumes are not large, resources are readily available to implement this component of the remedy.

### 7. Cost

Cost estimates are used in the CERCLA FS process to eliminate those remedial alternatives that are significantly more expensive than competing alternatives without offering commensurate increases in performance or overall protection of human health or the environment. The cost estimates developed are preliminary estimates with an intended accuracy range of +50 to –30 percent. Final costs will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables. The costs include both capital costs (including fixed-price remedial construction) and long-term O&M costs (post-remediation). Overall 30-year present value costs are developed for each alternative assuming a discount rate of 3.0 percent. Some alternatives have extensive capital costs but could result in a serious reduction in the alternative lifecycle to achieve the RAOs (e.g., less than 30 years). Other alternatives that do not rely on intensive upfront remediation technologies have a very long remediation lifecycle (i.e., well beyond 30 years) that would outweigh the alternatives with high capital cost. Because cost determination was limited to 30 years per CERCLA requirements, the alternatives with high capital costs (e.g., Alternatives 5 and 6) appear to be as or more expensive on a 30-year basis than alternatives with low capital costs but long lifecycle duration (e.g., Alternatives 2 and 3). The costs for Alternatives 2 and 3 would be substantially higher than the 30 year estimates since these alternatives are estimated to need to be implemented for several hundred years to achieve RAOs.

The progression of total present value costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 3, Alternative 4, Alternative 5, Alternative 2, and Alternative 6. There are no costs associated with Alternative 1 because no remedial activities would be conducted. Alternative 6 has highest capital costs due to the high cost of ZVI, but lower O&M costs than all other alternatives with the exception of Alternatives 3 and 5. Alternative 5 has an O&M cost over 20 years after which the GWTP and extraction would be shut down. Alternative 5 has a higher capital cost associated with thermal treatment compared to Alternatives 2, 3, and 4. Alternatives 2, 3, and 4 have the lowest capital costs of the active remedial alternatives, with Alternative 3 having the lowest capital cost associated with slurry wall construction and lowest O&M cost due to the greater cost reductions in O&M associated with reduction in GWTP operation and reduction in monitoring costs. Alternatives 2, 4, and 6 have the highest O&M costs of all the alternatives because it is assumed that GWTP operations would continue for 30 years with no reduction in extraction rates. Alternative 2 would also require implementation well beyond 30 years.

### 8. State/Support Agency Acceptance

The USEPA and TCEQ reviewed the Proposed Plan. Comments received from the USEPA and TCEQ during the Proposed Plan development have been incorporated. Both agencies concur with the preferred alternative.

### 9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be described and addressed in the Record of Decision (ROD) for the site.

## SUMMARY OF THE PREFERRED ALTERNATIVE

Alternative 5 – enhanced groundwater extraction and treatment, LUCs, EISB inside and outside containment area and in Wilcox formation, unsaturated soil excavation and off-site disposal, thermal DNAPL removal (see **Figure 6**) is the preferred alternative for LHAAP-18/24 and is consistent with the intended future use of the site as a national wildlife refuge. This alternative would achieve the RAOs for the site through the following major components:

- Continued use of the existing groundwater extraction system with enhancements (including a potentially phased reactivation of two existing ICTs [ICT 3 and 9]) until COC concentrations are low enough that MNA can address remaining contamination within the containment area.
- Continued operation of the current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane that would not require an Explanation of Significant Differences (ESD).
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind). The estimated cost to excavate soil beneath the UEP is included in this alternative and could be implemented in the future (e.g., depending on the results of the Five-Year Review of the groundwater remedy).
- Implementation of EISB of shallow zone groundwater outside the containment area at several locations; in the Wilcox formation at three or more locations, and inside the containment at five or more locations or as needed.
- Implementation of thermal desorption to remove DNAPL in two distinct areas inside the containment area at the site.
- MNA for both shallow and intermediate zone groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas (after evaluation of EISB) to reduce contaminant levels to cleanup levels and confirm the contaminated groundwater remains localized with minimal migration.
- Maintenance of existing cap over the former UEP.

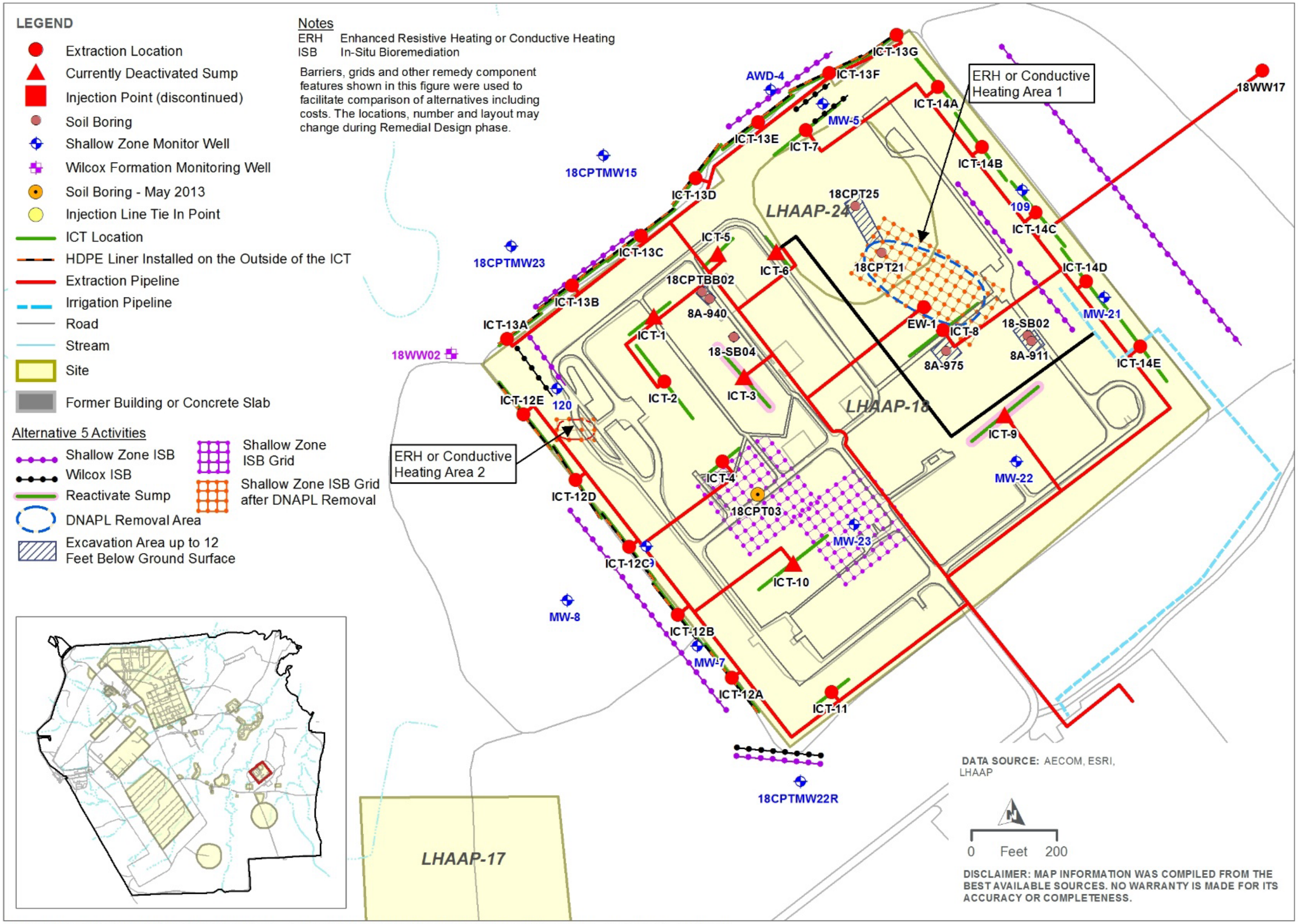


**Figure 6. LHAAP-18/24 Preferred Alternative 5**

- Long-term LUCs for the Shallow Zone and Wilcox Formation aquifers that will ensure protection of human health by preventing exposure until levels that allow for unlimited use and unlimited exposure have been attained.

Long-term monitoring and reporting would continue until the cleanup levels are achieved.

The thermal treatment using either ERH or conductive heating will remove TCE, MC, and other VOCs in high concentration areas, where DNAPL may exist. The decision to use either ERH or conductive heating will be made during the remedial design phase.

Based on information currently available, the U.S. Army believes the preferred alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the CERCLA §121(b) requirement used to evaluate remedial alternatives. The preferred alternative would: 1) be protective of human health and the environment; 2) comply with ARARs; 3) be cost-effective; 4) utilize a permanent solution; and 5) utilize an active treatment as a principal element. The selected remedy addresses the statutory preference for treatment to the maximum extent possible.

The U.S. Army intends to present details of the remediation in the RD for LHAAP-18/24.

The remedy selected in the ROD may change from the preferred alternative presented here, based on public comment.

Notification that the site is suitable for nonresidential use will accompany all transfer documents and will be recorded in the Harrison County Courthouse. CERCLA Five-Year Reviews will be performed to determine whether the remedy remains protective of human health and the environment.

## COMMUNITY PARTICIPATION

The U.S. Army, USEPA, and TCEQ provide information regarding LHAAP-18/24 through public meetings, the Administrative Record file for the facility, and announcements published in the Shreveport Times and Marshall News Messenger newspapers. The U.S. Army encourages comments from the public on this Proposed Plan. Comments can be submitted using the enclosed form.

The dates for the public comment period, the date, location, time of the public meeting, and the locations of the Administrative Record files are provided on the front page of this Proposed Plan. Comments received will be summarized and responses provided in the Responsiveness Summary section of the ROD. Any significant changes to the Proposed Plan, as presented in this document, will also be identified and explained in the ROD.

## CITED REFERENCE DOCUMENTS FOR LHAAP-18/24


AECOM, 2016a. *Final Updated Post-Screening Investigation Report – LHAAP-18/24 Longhorn Army Ammunition Plant, Karnack, Texas*, February.

AECOM, 2016b. *Draft Final Supplemental to the Updated Post-Screening Investigation Report, LHAAP-18/24, Longhorn Ammunition Plant, Karnack, Texas*, December.

AECOM, 2017. *Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas*, January.

Jacobs Engineering Corporation (Jacobs), 2001. *Remedial Investigation Report for the Group 2 Sites Remedial Investigation (Sites 12, 17, 18/24, 29, and 32) at the Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas, Final*, St. Louis, Missouri, April.

Texas Commission on Environmental Quality (TCEQ), 2006, *Updated Examples of Standard No. 2, Appendix II, Medium-Specific Concentrations*, March 21, 2006.


## GENERAL REFERENCE DOCUMENT LIST FOR LHAAP-18/24


AECOM, 2013. *Final Post-Screening Investigation Report for LHAAP-18/24, Burning Ground No. 3 and Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas*, December.

AECOM, 2016. *1,4-Dioxane Groundwater Sampling Methodology and Analytical Results for LHAAP-18/24 at Longhorn Army Ammunition Plant, Karnack, Texas*, February.

AGEISS, Inc., 2014. *Final Baseline Ecological Risk Assessment Addendum, Longhorn Army Ammunition Plant, Karnack, Texas. Longhorn Ammunition Plant, Karnack, Texas*, July.

AWD Technologies, Inc. (AWD), 1994a. *Draft Interim Remedial Action – Phase I, Evaluation of Thermal Treatment of On-Site Contaminated Soils and Buried Waste, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas*, February.

AWD, 1994b. *Physical Surveying and Other Field Data, Early Interim Action at Burning Ground No.3, LHAAP-18 & LHAAP-24 Burning Ground/ Washout Pond & Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Marshall, TX*, AWD Technologies, Inc., Rockville, MD, February.

DOW Environmental, Inc., 1995. *Interim Remedial Action Burning Ground No. 3 and Unlined Evaporation Pond*, March.

Jacobs Engineering Corporation (Jacobs), 2002. *Baseline Human Health and Screening Ecological Risk Assessment for the Group 2 Sites (Sites 12, 17, 18/24, 29, and 32) at the Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas, Final*, St. Louis, Missouri, August.

Shaw, 2007. *Final Installation-Wide Baseline Ecological Risk Assessment, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, Volume I: Step 3 Report, January, and Volume II: Steps 4 through 8, November.

U.S. Army Corps of Engineers (USACE), 1989. *Phase I RCRA Facility Investigation. (RFI), Active Burning Ground and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Marshall, Texas*, July.

USACE, 1993. *Data Summary Report of Investigations Results from 1976 through 1992 for Burning Ground 3 and Unlined Evaporation Pond*, May.

## GLOSSARY OF TERMS

**Administrative Record**—The body of reports, official correspondence, and other documents that establish the official record of the analysis, cleanup, and final closure of a CERCLA site.

**ARARs**—Applicable or relevant and appropriate requirements. Refers to the federal and state requirements that a selected remedy will attain.

**Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)**—This law authorizes the Federal Government to respond directly to releases (or threatened releases) of hazardous substances that may be a danger to public health, welfare, or the environment. The U.S. Army currently has the lead responsibility for these activities.

**Dense Non-Aqueous Phase Liquid (DNAPL)**—A liquid that is both denser than water and is immiscible in or does not dissolve in water.

**Enhanced In-situ Bioremediation (EISB)**—EISB of chlorinated solvents in groundwater involves the input of an organic carbon source, nutrients, electron acceptors, and/or microbial cultures to stimulate degradation.

**Environmental Media**—Major environmental categories that surrounds or contact humans, animals, plants, and other organisms (e.g., surface water, ground water, soil or air) and through which chemicals or pollutants move.

**Electrical Resistance Heating (ERH)**—An intensive in situ environmental remediation method that uses the flow of alternating current electricity to heat soil and groundwater and evaporate contaminants.

**Exposure**—Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lung, digestive tract, etc.) and available for absorption.

**Feasibility Study (FS)**—The process used for the development, screening, and detailed evaluation of alternative remedial actions.

**Groundwater**—Underground water that fills pores in soil or openings in rocks to the point of saturation.

**Hazard Index**—The hazard index is the sum of the hazard quotients for all chemicals to which an individual is exposed. A hazard index value of 1.0 or less indicates that no adverse non-cancer human health effects are expected to occur. Each hazard quotient is a comparison of an estimated chemical intake (dose) with a reference dose level below which adverse health effects are unlikely. Each hazard quotient is expressed as the ratio of the estimated intake (numerator) to the reference dose (denominator). The value is used to evaluate the potential for non-cancer health effects, such as organ damage, from chemical exposures.

**In-Situ Thermal Desorption (ISTD)**—An intensive thermally enhanced environmental remediation technology that uses conductance or resistance heating elements to directly transfer heat to environmental media to increase the volatility of contaminants such that they can be removed from the solid matrix. The volatilized contaminants are then either collected or thermally destroyed.

**Land Use Control (LUC)**—Administrative and legal controls or engineered and physical barriers to restrict land use that are put in place to minimize the potential for exposure to contamination and/or protect the integrity of a response action.

**Maximum Contaminant Level (MCL)**—The MCL is based on the National Primary Drinking Water Standard. The TCEQ has adopted MCLs at the regulatory cleanup level for both industrial and residential uses. Any detected compound in the groundwater samples with an MCL was evaluated by comparing it to its associated MCL.

**Monitored Natural Attenuation**—The process by which a compound is reduced in concentration over time, through absorption, adsorption, degradation, dilution, and/or transformation.

**Proposed Plan**—A report for public comment highlighting the key factors that form the basis for the selection of the preferred remediation alternative.

**Record of Decision (ROD)**—A public document that explains the cleanup method that will be used at a Superfund site, based on USEPA studies, public comments, and community concerns.

**Remedial Action**—The actual construction or implementation phase of a Superfund site cleanup that follows remedial design.

**Remedial Action Objectives (RAOs)**—RAOs are established to protect human health and the environment while also meeting ARARs. The identification of RAOs must consider the environmental impacts at the site and the receptors that are affected.

**Remedial Design (RD)**—The phase of the CERCLA process that follows the selection of a remedial action and includes development of technical specifications and engineering drawings and other requirements for implementing cleanup remedies and technologies.

**Remedial Investigation (RI)**—An in-depth study designed to gather data needed to determine the nature and extent of contamination at a CERCLA site.

**Risk Assessment**—An analysis of the potential adverse health effects (current and future) caused by hazardous substances at a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action). The assessment contributes to decisions regarding appropriate response alternatives.

**Superfund**—The common name used for CERCLA; also referred to as the Trust Fund. The Superfund Program was established to help fund cleanup of hazardous waste sites. It also allows legal action to force those responsible for sites to clean them up.

**Thermal Conduction Heating (TCH)**—An in-situ thermal desorption remediation process whereby heat is applied to subsurface soils and groundwater through an array of vertical or horizontal heater wells placed in the subsurface that heat the impacted area to temperatures that volatize the compounds of concern.

## ACRONYMS

| | |
|---|---|
| ACD | Air Curtain Destructor |
| ARARs | applicable or relevant and appropriate requirements |
| BHHRA | Baseline Human Health Risk Assessment |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| COC | chemical of concern |
| DCE | dichloroethylene |
| DNAPL | dense non-aqueous phase liquid |
| ECP | environmental condition of property |
| EISB | enhanced in-situ bioremediation |
| ERH | electrical resistance heating |
| ESD | Explanation of Significant Differences |
| FFA | Federal Facility Agreement |
| FS | Feasibility Study |
| GWP-Ind | soil MSC for industrial use based on groundwater protection |
| $^{GW}GW_{ing}$ | PCL for residential groundwater use |
| GWTP | groundwater treatment plant |
| HI | hazard index |
| ICT | interceptor-collection trench |
| ISTD | in-situ thermal desorption |
| IRA | Interim Remedial Action |
| LHAAP | Longhorn Army Ammunition Plant |
| LUCs | land use controls |
| MC | methylene chloride |
| MCL | maximum contaminant level |
| µg/L | micrograms per liter |
| MNA | monitored natural attenuation |
| MSC | medium-specific concentration |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NPL | National Priorities List |
| O&M | operation and maintenance |
| OSHA | Occupational Safety and Health Administration |
| PCE | tetrachloroethylene |
| PCL | protective concentration level |
| PPE | personal protective equipment |
| PSI | Post-Screening Investigation |
| RAB | Restoration Advisory Board |
| RAO | Remedial Action Objective |
| RD | Remedial Design |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| TCA | trichloroethane |
| TCE | trichloroethylene |
| TCEQ | Texas Commission on Environmental Quality |
| TCH | thermal conduction heating |
| TRRP | Texas Risk Reduction Program |
| UEP | Unlined Evaporation Pond |
| USEPA | U.S. Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| VOC | volatile organic compound |
| ZVI | zero-valent iron |

## USE THIS SPACE TO WRITE YOUR COMMENTS

Your input on the Proposed Plan for LHAAP-18/24 is important to the U.S. Army. Comments provided by the public are valuable in helping the U.S. Army select a final remedy for these sites.

You may use the space below to write your comments, then fold and mail to Dr. Rose M. Zeiler, P.O. Box 220, Ratcliff, Arkansas 72951. Comments must be postmarked by May 2, 2019. If you have questions about the comment period, please contact Dr. Rose M. Zeiler directly at (479) 635-0110. Those with electronic communications capabilities may submit their comments to the U.S. Army via Internet at the following e-mail address: rose.m.zeiler.civ@mail.mil