DEPARTMENT OF THE ARMY
LONGHORN ARMY AMMUNITION PLANT
POST OFFICE BOX 220
RATCLIFF, AR 72951

December 26, 2019

DAIM-ODB-LO

Mr. Rich Mayer
U.S. Environmental Protection Agency
1201 Elm Street, Suite 500
Dallas, TX 75270-2002

Re: Draft Final Remedial Design/Remedial Action Work Plan, Contingency Remedy, LHAAP-50 Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas, December 2019

Dear Mr. Mayer,

One hard copy and one compact disc (CD) of the above-referenced document are being transmitted to you for your records. The document includes revisions based upon the Environmental Protection Agency's (EPA) comments on the Draft version received on November 27, 2019, and Texas Commission on Environmental Quality's (TCEQ) comments received on November 25, 2019. In accordance with Federal Facility Agreement, this Draft Final will be considered Final after 30 days without further comment. Response to comments on the Draft version of the document are included with this Draft Final.

The document was prepared by Bhate Environmental Associates, Inc., (Bhate) team, on behalf of the Army as part of Bhate's Performance Based Remediation contract for the facility. I ask that Kim Nemmers, Bhate's Project Manager, be copied on any communications related to the project.

The point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by email at rose.m.zeiler.civ@mail.mil.

Sincerely,

Rose M. Zeiler

Rose M. Zeiler, Ph.D.
Longhorn AAP Site Manager

Copies furnished:
A. Palmie, TCEQ, Austin, TX (1 hard copy and 1 CD)
P. Bruckwicki, Caddo Lake NWR, TX (1 hard copy and 1 CD)
R. Smith, USACE, Tulsa District, OK (Electronic only)
A. Williams, USACE, Tulsa District, OK (1 CD)

N. Smith, USAEC, San Antonio, TX (1 CD)
K. Nemmers, Bhate, Lakewood, CO (1 CD)
P. Srivastav, APTIM, Houston, TX

DEPARTMENT OF THE ARMY
LONGHORN ARMY AMMUNITION PLANT
POST OFFICE BOX 220
RATCLIFF, AR 72951

December 26, 2019

DAIM-ODB-LO

Ms. April Palmie
Texas Commission on Environmental Quality
Superfund Section, MC-136
12100 Park 35 Circle, Bldg. D
Austin, TX 78753

Re: Draft Final Remedial Design/Remedial Action Work Plan, Contingency Remedy, LHAAP-50 Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas, December 2019

Dear Ms. Palmie,

One hard copy and one compact disc (CD) of the above-referenced document are being transmitted to you for your records. The document includes revisions based upon the Environmental Protection Agency's (EPA) comments on the Draft version received on November 27, 2019, and Texas Commission on Environmental Quality's (TCEQ) comments received on November 25, 2019. In accordance with Federal Facility Agreement, this Draft Final will be considered Final after 30 days without further comment. Response to comments on the Draft version of the document are included with this Draft Final.

The document was prepared by Bhate Environmental Associates, Inc., (Bhate) team, on behalf of the Army as part of Bhate's Performance Based Remediation contract for the facility. I ask that Kim Nemmers, Bhate's Project Manager, be copied on any communications related to the project.

The point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by email at rose.m.zeiler.civ@mail.mil.

Sincerely,

Rose M. Zeiler, Ph.D.
Longhorn AAP Site Manager

Copies furnished:
R. Mayer, USEPA Region 6, Dallas, TX (1 hard copy and 1 CD)
P. Bruckwicki, Caddo Lake NWR, TX (1 hard copy and 1 CD)
R. Smith, USACE, Tulsa District, OK (Electronic only)

A. Williams, USACE, Tulsa District, OK (1 CD)
N. Smith, USAEC, San Antonio, TX (1 CD)
K. Nemmers, Bhate, Lakewood, CO (1 CD)
P. Srivastav, APTIM, Houston, TX

Response to Comments on
Draft Remedial Design / Remedial Action Work Plan
LHAAP-50 Former Sump Water Tank,
Longhorn Army Ammunition Plant, Karnack, Texas

Document Date: 31 October 2019
Comment Date: 25 November 2019

Reviewer: April Palmie, TCEQ
Respondent: Dr. Rose Zeiler

1. Respondent Concurs (C), Does Not Concur (D), Takes Exception (E), or Delete (X)
2. Commenter Agrees (A) with response, or Does Not Agree (D) with response

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X	Response	A or D[2]
1.	2.2, 2-2	2nd paragraph has old language that should be removed or revised (regarding well already installed): Based on the regulatory comments received in the Final RAWP (AECOM 2013), an additional well is proposed for installation in Summer 2019 to evaluate how far plumes extend downgradient of 50WW12 as shown in Figure 2-1. Results from the new well will be used to refine the extent of the plumes in groundwater.	C	Text in Section 2.2, page 2-2 will be revised as follows: "Based on the regulatory comments received in the Final RAWP (AECOM 2013) and recommendations made in the 2018 Five Year Review (USACE 2019), an additional well, 50WW29, was installed in August 2019 to evaluate the extent of the plume downgradient of 50WW12 as shown in Figure 2-1."	

2.	4.2.2, 4-1	Notification - TCEQ needs 30-days for UIC coordination	C	Comment noted. UIC information will be provided to TCEQ 30 days prior to the commencement of field work.	
3.	Figure 2-1	Why does this figure show 50WW29 as a proposed well? Is this figure necessary?	C	Figure 2-1 will be revised to show 50WW29 as an installed well instead of "proposed well".	

Response to Comments on
Draft Remedial Design / Remedial Action Work Plan
LHAAP-50 Former Sump Water Tank,
Longhorn Army Ammunition Plant, Karnack, Texas

Document Date: 31 October 2019
Comment Date: 27 November 2019

Reviewer: Mr. Richard Mayer, USEPA
Respondent: Dr. Rose Zeiler

Comment Ref. #	Section, Page Ref.	EPA Comment	C, D, E, or X	Response	A or D[2]
1.	2.1, 2-1, Last Paragraph	The Army's estimates of groundwater flow rates (.11 ft/year to .39 ft/year) are inconsistent with the field data. At Site 50, contaminants have travelled at least 375 feet from their source, an old AST, which was installed in 1955. The groundwater flow rate must be around six ft/yr. Did the Army use the correct groundwater flow rate formula? The correct groundwater flow rate formula is found in Appendix A.	C	Using a gradient of 0.00427 based on the May 2018 potentiometric surface, we recalculated the values using a hydraulic conductivity range of 5.5x10-5 cm/sec to 1.9x10-4 cm/sec and an estimated effective porosity of 0.35, which resulted in a range of flow rates from 0.73 to 2.19 ft per year. The flow rates estimated by the Army are based on calculations using the current hydraulic gradient information, hydraulic conductivity values from past testing, and estimated values for effective porosity. The calculation yields a snapshot of the current conditions, but is not reflective of past conditions. It is likely that there were other factors influencing the hydraulic gradient when the site was active that may have resulted in much higher flow rates.	

				The last sentence of Section 2.1 has been revised with the recalculated values to read as follows: "Using an estimated hydraulic gradient in May 2018 of 0.00427 feet per foot (ft/ft), the calculated groundwater flow velocity in the shallow zone ranges from 0.73 feet per year (ft/year) to 2.19 ft/year.	
2.	Table 2-2 & 3-2	Please provide the analytical method used for VOCs and perchlorate in the parameter/analysis row (plus other parameters without a method).	C	The analytical methods for VOCs and perchlorate are SW8260 and SW6850 respectively. Tables 2-2 and 3-2 will be revised to include the analytical methods.	
3.	Figure 2-1	The line from the 50WW12 results table to monitoring well 50WW12 extends past the well location.	C	Figure 2-1 will be revised to remove the line extending past the well location.	
4.	Table 3-1	The method for analyzing for perchlorate in groundwater should be 6850. Method 314.0 does not require filtering of the groundwater samples to remove microbes (which can biodegrade the perchlorate). Also, this method historically tends to have more false positive and negative analytical results. In addition, please include the analytical method for VOCs. EPA assumes method 8260 will be used.	C	Table 3-1 will be revised to include analytical method SW6850 used for perchlorate.	

5.	Table 4-1	Why are DPTs 07-12 stopping at 35 feet, instead of 60 feet, as is the case for DPTs 01-06? Please explain.	C	Upon review of extent of contamination and drill logs in the proposed treatment area, high perchlorate and/or TCE concentrations are known to exist in the upper and lower shallow zone in the vicinity of wells 50WW11, 50WW13 and 50WW14, and in the upper shallow zone in the vicinity of 50WW12. ISB is proposed in the known areas of contamination. DPTs 01 – 06 are proposed to treat both upper shallow and lower shallow zones because contamination is known to be present in both zones. At the upper shallow well 50WW13, perchlorate was detected at 640 µg/L in May 2018 and 130 µg/L in May 2019. At the lower shallow well 50WW14, TCE was detected 33 µg/L in 2018 although TCE or perchlorate were not detected in May 2019. At the upper shallow well 50WW11, perchlorate was detected at 1,000 µg/L in May 2018 and at 450 µg/L in May 2019. Since contamination exists in the upper shallow zone as of 2019, and existed in the lower shallow zone near 50WW14 as of 2018, it is proposed to treat both the upper and lower shallow zones in the vicinity of 50WW11, 50WW13 and 50WW14. Injections conducted in the lower shallow zone in this area will also help remediate lower levels of perchlorate and TCE observed in the downgradient lower shallow zone well 50WW06.	

				At the upper shallow well 50WW12, perchlorate was detected at 91,000 µg/L in May 2018 and at 65,000 µg/L in May 2019. ISB treatment is proposed in the upper shallow zone in the vicinity of 50WW12 where contamination is known to exist.	
6.	Page 4-5	There should be a statement indicating that Goose Prairie Creek will be inspected periodically during the day to ensure daylighting from the injections are not occurring in the creek.	C	Following text will be added to the paragraph: "Goose Prairie Creek will be monitored during and after injections for decrease in DO and visual changes in water color along the creek. Additional monitoring and visual observations will be conducted to determine if any decrease in DO is from injection materials or changes in environmental conditions."	
7.	Figure 1-5, Figure 2-1 and Figure 3-1	Please locate the intermediate well on these figures	C	Figure 1-5, Figure 2-1 and Figure 3-1 will be revised to include intermediate wells.	
8.	General Comment	What are the last monitoring results for monitoring 50WW02?	C	The last sampling event for monitoring well 50WW02 was 4/3/2009. Perchlorate was detected at 110 ppb, TCE at 8,050 ppb, cis-1,2-DCE at 978 ppb and 1,2-DCA at 18 ppb in May 2009.	
9.	General Comment	Although this comment does not directly apply to this document, as a reminder for the future, there will be a need for a lower shallow	C	Comment noted.	

		monitoring well near upper shallow monitoring well 50WW12 (91,000 ug/L). Currently, lower shallow monitoring well 50WW09, which is near the source, contains no perchlorate. However, another lower shallow monitoring well, 50WW06, approximately 200 feet farther from the source contains perchlorate at 220 ug/l (2018). Thus, the fact that perchlorate is not present near the source in the lower shallow zone does not mean that it is not present farther from the source in the lower shallow zone. Also, there may be a need for an additional intermediate well in the future. If you look at the current plume shape/geometry, the only intermediate well is located near the source at the very western edge. The plume extends northeasterly for approximately 375 feet. The most contaminated well for perchlorate is 50WW12 and it is the most eastern well within the plume. So according to future groundwater results (if a lower shallow well is installed), an intermediate well may be needed.			

Draft Final

Remedial Design/Remedial Action Work Plan, Contingency Remedy, LHAAP-50 Former Sump Water Tank

Longhorn Army Ammunition Plant
Karnack, Texas

Prepared for
U.S. Army Corps of Engineers, Tulsa District
Contracting Division
2488 East 81st Street
Tulsa, Oklahoma 74137-4290

Prepared by

bhate
ENVIRONMENT & INFRASTRUCTURE

1608 13th Avenue South, Suite 300
Birmingham, Alabama 35205
1-800-806-4001 • www.bhate.com

Prepared by

APTIM

Aptim Federal Services, LLC
2500 CityWest, Suite 1700
Houston, Texas 77042

Contract No. W9128F-13-D-0012
Task Order No. W9128BV17F0150
Project No. 501032
Rev 0
December 2019

Table of Contents

Table of Contents *(continued)*

List of Tables

List of Figures

List of Appendices

This page intentionally left blank.

Acronyms and Abbreviations

µg/L	micrograms per liter
AECOM	AECOM Technical Services, Inc.
APTIM	Aptim Federal Services, LLC
AST	aboveground storage tank
bgs	below ground surface
Bhate	Bhate Environmental, Inc.
cm/s	centimeters per second
COC	chemical of concern
DAP	diammonium phosphate
DO	dissolved oxygen
DPT	direct-push technology
EDS–ER™	electron donor solution–extended release
ESD	explanation of significant differences
EVO	emulsified vegetable oil
ft/ft	feet per foot
ft/year	feet per year
GPS	global positioning system
ISB	in-situ bioremediation
IWWP	Installation-Wide Work Plan
Jacobs	Jacobs Engineering Group, Inc.
LHAAP	Longhorn Army Ammunition Plant
LTM	long-term monitoring
LUC(s)	land use control(s)
MATOC	Multiple Award Task Order Contract
MCL	maximum contaminant level
MNA	monitored natural attenuation
ORP	oxidation-reduction potential
PCL	protective concentration level
psi	pounds per square inch
RACR	Response Action Completion Report
RAO	remedial action objectives
RA-O	remedial action operation
RAWP	Remedial Action Work Plan
RD	Remedial Design

Acronyms and Abbreviations *(continued)*

ROD	Record of Decision
ROI	radius of influence
SDC-9™	APTIM's dechlorinating culture
Shaw	Shaw Environmental & Infrastructure, Inc.
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
TO	Task Order
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Tulsa District, contracted Bhate Environmental, Inc. (Bhate) under the Omaha Multiple Environmental Government Acquisition National Small Business Multiple Award Task Order Contract (MATOC), Environmental Remediation Services with Military Munitions Response Program, Task Order (TO) Number (No.) W9128BV17F0150, to conduct environmental restoration at multiple sites at the former Longhorn Army Ammunition Plant (LHAAP). The Bhate Team is comprised of Bhate and Aptim Federal Services, LLC (APTIM). LHAAP is a closed government owned, formerly contractor operated and maintained, Department of Defense facility located central east Texas (**Figure 1-1**).

A *Final Record of Decision* (ROD) was executed for LHAAP-50 in September 2010 (USACE 2010). Groundwater monitoring at LHAAP-50 is ongoing as described in the *Final Remedial Action Completion Report* (AECOM 2016). The Remedial Action Work Plan (RAWP) for the entire site was prepared in June 2013 in accordance with the ROD and implemented in July 2013. The monitored natural attenuation (MNA) remedy for the comingled trichloroethene (TCE) and perchlorate plume at this site, as presented in the ROD calls for an evaluation of the remedy after two years of MNA remedial action operation (RA-O) and implementation. The ROD also states that the long-term monitoring (LTM) associated with this remedy will be used to track the continued effectiveness of MNA and will continue once every five years until cleanup levels are achieved. The ROD also provides for the implementation of a contingency remedy to enhance MNA if MNA is found to be ineffective. The *Draft Final Third Annual Remedial Action Operation Report* (Bhate 2018a) concluded that MNA is ineffective and implementation of a contingency remedy would be appropriate. A *Draft Explanation of Significant Differences* (Bhate 2019) was submitted to the U.S. Environmental Protection Agency (USEPA) and the Texas Commission on Environmental Quality (TCEQ) in April 2019 for changes to the ROD to implement the contingency remedy consisting of in-situ bioremediation (ISB). Therefore, this RAWP for the contingency remedy addresses ISB implementation for the groundwater plume at this site, based on the Remedial Design (RD) for the LHAAP-50 site, which was approved by regulatory agencies in September 2011 (Shaw 2011).

1.1 Organization of Work Plan

This work plan is composed of the following sections:

- **Section 1.0:** "Introduction" summarizes the site background, proposed remedy including the chemicals of concern (COCs) and their respective cleanup levels, the nature and extent of contamination and remedial action objectives (RAOs).
- **Section 2.0:** "Site Characteristics" summarizes the hydrogeology of the site, as well as the nature and extent of contamination and the proposed contingency remedy.
- **Section 3.0:** "Land Use Control Remedial Design/Plan" references the Final RAWP for LHAAP-50 (AECOM 2013) wherein the Land Use Control Plan is presented.
- **Section 4.0:** "In Situ Bioremediation Work Plan" describes the injection activities and methodologies to be implemented for the ISB component of the remedy.
- **Section 5.0:** "Post-Remedial Monitoring and Reporting" describes the remedial performance monitoring and reporting that will be performed after ISB injections.
- **Section 6.0:** "Schedule" describes the proposed implementation schedule for the remedial action activities.
- **Section 7.0:** "References" provides a list of references cited in the document.

This work plan also includes the following appendices supporting the main text:

- **Appendix A** includes the calculation sheets and proposed injection volume worksheets for the ISB component of the remedy.
- **Appendix B** includes the safety data sheets for the proposed injection amendments, Electron Donor Solution–Extended Release (EDS–ER™) and APTIM's dechlorinating culture, SDC-9™.
- **Appendix C** includes a blank injection log that will be used in the field to track injection volumes, flow rates and pressures.

1.2 Site Description

LHAAP-50 (former sump water tank) is in the north-central portion of LHAAP and covers an area of approximately 1 acre (**Figure 1-2**). The site is an open area of grass and brush that is bounded by South Crocket Avenue to the northeast, a drainage ditch to the west, a railroad spur to the south, and Goose Prairie Creek to the north. Runoff from the northeastern portion of the site is generally toward the northeast. Runoff is collected by a drainage ditch to the northeast that runs parallel to South Crockett Avenue and eventually joins Goose Prairie Creek. Runoff from the southwestern portion of the site is collected to the west by a drainage ditch that carries the runoff north into Goose Prairie Creek. Goose Prairie Creek eventually empties into Caddo Lake.

When operational, LHAAP-50 contained a 47,000-gallon capacity aboveground storage tank (AST) which received industrial wastewater from various industrial waste production sumps throughout LHAAP between 1955 and 1988. After the solids were filtered, the storage tank contents were discharged into Goose Prairie Creek upstream of the Goose Prairie Creek bridge on South Crockett Avenue, south of 51st Street. The flow in the creek was sufficient to dilute the water to safe levels (Jacobs 2002). If natural flow in the creek was considered insufficient, clean water was reportedly pumped into the creek to dilute the contents. The AST is no longer present.

The land use control (LUC) area associated with the groundwater use restriction at LHAAP-50 extends beyond the northern, southern, eastern, and western historical site boundaries and encompasses a total of approximately 77.19 acres (see **Figure 1-3**). The nearest significant surface water body to LHAAP-50 is Goose Prairie Creek, located approximately 80 feet north of the site, which eventually flows into Caddo Lake. LHAAP-50 has no known areas of archaeological or historical importance.

1.2.1 Contingency Remedy

The description of the proposed groundwater remedy at LHAAP-50 in Section 2.9.1 of the ROD was Excavation, MNA and LUC (USACE 2010). The ROD stated that a contingency remedy to enhance MNA would be implemented to reach the RAOs if MNA was found to be ineffective and would be documented in the Explanation of Significant Difference (ESD).

Soil excavation of perchlorate contaminated soil was conducted in July 2013 followed by MNA of the commingled plume in groundwater. The most recent potentiometric surface information for the site (May 2018) is shown on **Figure 1-4** and **Figure 1-5** presents the analytical results from the monitoring wells during the May 2018 RA-O sampling event (Bhate 2018b). As discussed in the ROD (USACE 2010) and Fourth Annual RA-O Report (Bhate 2018b), the COCs at LHAAP-50 include dissolved phase perchlorate and volatile organic compounds (VOCs), tetrachloroethene, TCE, 1,1-dichloroethene, 1,2-dichloroethane, cis-1,2-dichloroethene and vinyl chloride in groundwater, and perchlorate in soil. The groundwater cleanup levels for LHAAP-50 are presented on **Table 1-1**.

Overall, the TCE and perchlorate plumes in groundwater appear to be relatively stable. At monitoring wells 50WW05, 50WW08, and 50WW14, significant decreasing trends were observed over four years, indicating that natural attenuation is occurring. However, an increasing trend was observed at monitoring well 50WW12 and no trends were observed at monitoring wells 50WW09, 50WW11, and 50WW13. The highest perchlorate concentration in May 2018 was detected at 50WW12 at 91,000 micrograms per liter (µg/L) while the highest TCE concentration in May 2018 was detected at 50WW13 at 620 µg/L (Bhate 2018b). Therefore, the proposed ISB contingency remedy will include ISB in areas of historical hotspots in the vicinity of wells 50WW12, 50WW11, and 50WW13.

The remedy at LHAAP-50 is intended to protect human health and the environment by preventing human exposure to the contaminated groundwater and preventing contaminated groundwater from migrating into nearby surface water. The final remedy will consist of LUC (already implemented), ISB, MNA, and LTM/Five Year Reviews.

The specific remedy components are discussed below:

- LUCs have been implemented for the impacted area as described in the Response Action Completion Report (RACR) (AECOM 2016) to ensure the protection of human health by restricting the use of groundwater. The LUC will remain in place until the cleanup levels are met.
- ISB will be implemented in the area where the highest concentrations are observed in the upper and lower shallow groundwater in the vicinity of wells 50WW11 and 50WW13, and in the shallow groundwater in the vicinity of well 50WW12. ISB is the process of removing contaminant mass by enhancing microbial populations that will utilize the contaminants in groundwater during respiratory or metabolic activities. The treatment involves injecting amendments which may include microbial cultures, electron donor sources, and nutrients into the subsurface.
- MNA constitutes a passive treatment where the contaminant concentrations decrease through natural attenuation processes such as biodegradation, dispersion, dilution, sorption, and volatilization (USEPA 1998).
- Data from performance monitoring is used to evaluate whether natural attenuation is occurring and reducing COCs. MNA will be implemented to verify that the TCE and perchlorate plumes are stable and will not migrate to nearby surface water at levels that may present an unacceptable risk to human health and the environment. MNA will return groundwater to its potential beneficial use, wherever practicable, after successful implementation of the ISB. MNA will be evaluated annually, with groundwater monitoring performed on a quarterly basis for the first two years after implementation of ISB as described in **Section 5.1.2**.
- LTM: LTM will be conducted annually until the next Five Year Review. However, LTM will continue at least once in five years until cleanup levels are achieved. A cleanup time has not been estimated and will be evaluated following the implementation of ISB.

1.2.2 Remedial Action Objectives

The RAOs for LHAAP-50, consistent with the reasonably anticipated future use as a national wildlife refuge, are:

- Protection of human health by preventing human exposure to the contaminated groundwater
- Protection of human health and environment by preventing contaminated groundwater from migrating into nearby surface water
- Protection of human health by preventing further potential degradation of groundwater and surface water from contaminated soil
- Return of groundwater to its potential beneficial uses as drinking water, wherever practicable

This page intentionally left blank.

2.0 SITE CHARACTERISTICS

2.1 Site Hydrogeology

The shallow unconfined aquifer extends from the ground surface to 60 feet below ground surface (bgs) across the site. While intermittent clay layers are present, no true aquiclude exists to prevent vertical communication between ground surface and approximately 60 feet bgs. Because the shallow zone is approximately 60 feet in thickness, the potential for differences in nature and extent of contaminant impacts between upper and lower portions of the shallow zone was recognized. To evaluate this concept, 27 new wells were installed in configurations to separately monitor the upper portion of the shallow zone (18 wells) and the lower portion of the shallow zone (six wells). Additionally, three fully penetrating wells (50WW17, 50WW19, and 50WW20) were installed with screened intervals across the entire saturated shallow zone (Bhate 2018b). Monitoring well locations are shown on **Figure 1-3**. Well Construction information is included in **Table 2-1**.

The ‘upper shallow’ zone refers to the zone from ground surface to 30 feet bgs, the ‘lower shallow’ zone refers to the zone from 30 to 60 feet bgs, the intermediate zone is the zone greater than 100 feet bgs. The intermediate water bearing zone underlies the shallow zone at approximately 100 feet bgs (Bhate 2018b).

Hydraulic conductivities in the shallow zone wells varied from 5.5×10^{-5} to 1.9×10^{-4} centimeters per second (cm/s) (Jacobs 2002) and groundwater flow in the shallow and intermediate zones is generally to the east and northeast. Using an estimated hydraulic gradient in May 2018 of 0.00427 feet per foot (ft/ft), the calculated groundwater flow velocity in the shallow zone ranges from 0.73 feet per year (ft/year) to 2.19 ft/year.

2.2 Nature and Extent of Contamination

The nature and extent of contamination a LHAAP-50 was evaluated during field investigations conducted between 1992 and 2010. The AST was the most likely source of contaminants released into the environment. Since the AST has been removed, there is no longer a potential release mechanism for leaks or spills. Perchlorate and VOCs were released via overland spills, and discharges to the soil and adjacent surface water.

The area of perchlorate contamination in soil was small and the concentration of perchlorate did not pose an unacceptable risk to human health or ecological receptors. The perchlorate in soil is no longer present after removal and offsite disposal of approximately 183 cubic yards of perchlorate contaminated soil in September 2013 as described in the Final RACR (AECOM 2016). An area of groundwater contamination is present in the shallow groundwater (upper and lower zones) which poses an unacceptable carcinogenic risk and non-carcinogenic hazard. There is no groundwater contamination in the intermediate zone. The potential exposure pathways are via use of groundwater as drinking water and migration of impacted groundwater into surface water. Shallow groundwater is not used as drinking water at the refuge and this potential exposure pathway is eliminated from any hypothetical receptor because LUCs are in place that prohibit the use of groundwater, other than environmental monitoring and testing. The nearest significant surface water body to LHAAP-50 is Goose Prairie Creek, approximately 80 feet to the north of the site.

Figure 1-5 presents the estimated VOC and perchlorate plumes as of May 2018. The TCE plume is slightly larger than the perchlorate plume. The TCE and perchlorate plume start in the vicinity of 50WW09 and extend to downgradient well 50WW12 (Bhate 2018b). Based on the regulatory comments received in the Final RAWP (AECOM 2013) and recommendation made in the 2018 Five Year Review (USACE 2019), an additional well, 50WW29, was installed in August 2019 to evaluate the extent of the plume downgradient of 50WW12 as shown in **Figure 2-1**. Results from the new well will be used to refine the extent of the plumes in groundwater.

2.3 Monitoring Well Installation and Sampling

Based on recommendations made in the 2018 Five Year Review (USACE 2019), a new monitoring well, 50WW29, was installed to the northeast of 50WW12 in August 2019 in the upper shallow zone with the same screened interval as monitoring well 50WW12 from 20 to 35 feet bgs. The monitoring well was installed in accordance with the Installation Wide Work Plan (Bhate 2018c) and was developed and sampled following the installation. The COCs were detected at concentrations below the maximum contaminant level/protective concentration level (MCL/PCL). Groundwater sampling results for 50WW29 are included in **Table 2-2**. The boring log and Well Construction information are included in **Appendix A**.

3.0 IN-SITU BIOREMEDIATION REMEDIAL DESIGN

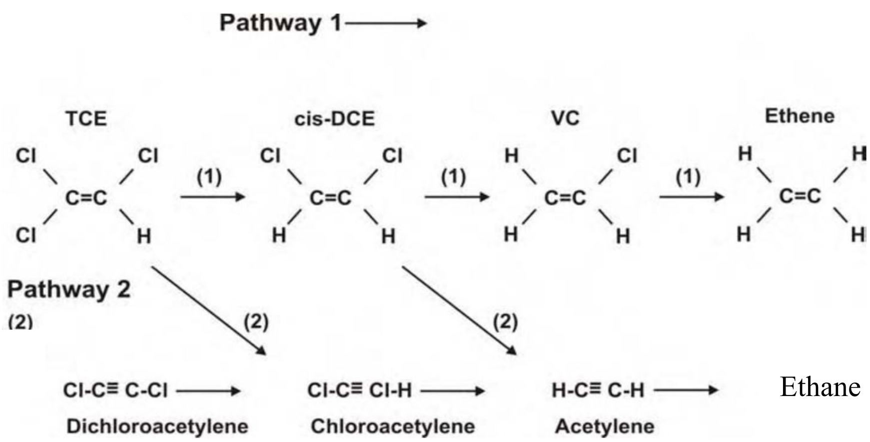
In general, implementation of ISB will include injection of an electron donor/substrate, microbial culture and nutrients in the subsurface. The indigenous microorganisms will grow and multiply using injected substrate as a carbon and energy source, thereby degrading perchlorate. The schematic showing the degradation pathway for perchlorate and chlorinated VOCs is provided below:

Perchlorate Degradation Pathway

$$ClO_4^- \longrightarrow ClO_3^- \longrightarrow ClO_2^- \longrightarrow Cl^- + O_2$$

Perchlorate → Chlorate → Chlorite → Chloride + Oxygen

Biotic and Abiotic Degradation Pathways – Chlorinated VOCs



ISB will be implemented at LHAAP-50 to remediate groundwater impacted with high levels of perchlorate and VOCs, where MNA has proven to be ineffective. The 2018 data discussed in **Section 1.2.1** indicates an increasing trend at monitoring well 50WW12 and no trends at monitoring wells.50WW09, 50WW11, and 50WW13 (Bhate 2018b). The highest perchlorate concentration in May 2018 was detected at 50WW12 at 91,000 µg/L while the highest TCE concentration in May 2018 was detected at 50WW13 at 620 µg/L. Therefore, the proposed ISB contingency remedy will include ISB in areas of historical hotspots in the vicinity of wells 50WW12, 50WW11, and 50WW13. The ISB system has been designed and implemented to remediate perchlorate and VOCs in the groundwater down to the MCL/PCL using emulsified vegetable oil (EVO), microbial culture (SDC-9™) and nutrients. The EVO and nutrients will be mixed with water and injected using temporary direct-push technology (DPT) injection points within the plume area. The specific basis for the various design parameters selected is described in the following sections. Field implementation procedures for the ISB remedy are described in **Section 5.0**. ISB calculation sheets used to develop the design parameters described below are provided in **Appendix A**.

3.1 Substrate Injection Strategies

The ISB substrate will be injected at 12 temporary DPT locations spaced approximately 20 to 25 feet apart as shown on **Figure 3-1**. A DPT injection system will be used to inject substrate over an interval coinciding with the saturated water bearing interval at each proposed injection point. The treatment interval depth will vary depending on the lithologic information from the wells and borings nearest to each injection location.

Several direct push injection points may be manifolded for simultaneous injection to maximize delivery efficiency. The substrate will normally be injected at relatively low pressures (generally less than 40 pounds per square inch [psi]) to avoid development of preferential flow pathways within the formation and/or surfacing of injection fluids, although higher pressures may be needed in tight formations. The injection pressure at each injection location will be dictated by the formation back pressure on the pumping system but will be controlled by use of pressure relief valves.

The substrate solution will be injected using a top down or bottom up approach at each proposed injection point depending on the lithology and field conditions. Amendments will be pumped down through the DPT drill rod to the injection interval and amendment will be forced through the stainless steel screen into the surrounding formation. The tools will then be moved to the next injection depth and the amendment will again be pumped through the rods. This cycle will be repeated to provide coverage across the entire vertical treatment interval.

If the amendment delivery is not successful at a selected depth interval, the remaining volume may be injected into the same injection point at a different depth interval or into an adjacent injection point at the same or different depth interval.

3.2 Radius of Influence and Injection Point Spacing

The low hydraulic conductivity of the shallow groundwater zone suggests that the radius of influence (ROI) for each DPT injection location will be low. Based on our experience at other locations on LHAAP and knowledge of the hydrogeologic conditions described in **Section 2.1.1**, the ROI used to calculate the number of points needed was 10 feet, and the DPT injection point spacing will be 20 to 25 feet.

3.3 Substrate Selection

EVO was selected as the substrate for ISB because of the relative ease of injection and the long lifespan of the substrate. The specific formulation of EVO used to develop the injection volumes for this project is EDS–ER™ available from Tersus Environmental (**Appendix B**). EDS–ER™ is a water-mixable oil formulated with 100% EVO content (no water in the emulsion). EDS–ER™ is a food-grade carbon and is made from renewable crop-based oils. The use of EDS–ER™ or equivalent is expected to be cost-effective since it would eliminate the need for continuous or more frequent injection of substrate into the subsurface.

EDS–ER™ is provided by the vendor as water-mixable oil that contains no water as shipped; therefore, it will be mixed with water in the field. Use of EDS–ER™ or an equivalent volume of a similar product will reduce the cost and environmental footprint associated with transportation of higher volumes of more dilute substrate to the site. The product mixes easily with water and does not require high energy mixers. It formulates a completely miscible product when mixed with water (it does not create emulsions or particles in water), thus preventing clogging effects when injected in groundwater. A mixing tank will be used to mix the product with water. The product will be added to the tank in the volume desired, followed by pumping clean potable water into the tank to produce the mixture with the design concentration for injection. No mixers will be required due to the nature of the EDS–ER™ oil. The manufacturer's product information sheet is provided in **Appendix B**.

Bioaugmentation will be conducted by injecting SDC-9™. Nutrients in the form of diammonium phosphate (DAP) will provide essential levels of nitrogen and phosphate required for microbial activity. The nutrients will be added to each mixed batch following addition of the mix water, prior to injection. Additionally, a buffer, sodium bicarbonate will also be added to the mixture in order to maintain neutral pH levels in the aquifer. A buffer capacity test was conducted to determine the appropriate quantity of buffer to be added to the treatment area. The test was conducted using soil and groundwater samples collected during the installation of monitoring well 50WW29 (**Section 2.1.3**). Results of the buffer capacity test were used to determine the quantity of buffer and added to **Table 4-1**.

3.4 Substrate Loading and Injection

The mass of EVO required for the shallow treatment zone shown on **Figure 3-1** was estimated based on comparison of: 1) the stoichiometric demand exerted by the native (e.g., dissolved oxygen [DO], nitrate, and sulfate) and anthropogenic electron acceptors, and 2) the quantity of EVO necessary to treat the entire treatment zone when accounting for adsorption to the aquifer material. These calculations were performed using the EOS® Remediation Source Area and dense non-aqueous phase liquid Design Worksheet version 2.1f dated June 18, 2008. **Appendix A** provides the input and output calculations spreadsheets. The higher of the two values is used for the planned injection quantities.

The aquifer treatment demand in the vicinity of 50WW12 based on EOS's 60% carbon product is 2,606 pounds (**Appendix A**). That is equivalent to 1,564 pounds of 100% carbon EDS-ER™.

The gallons concentrated solution of EDS–ER™ will be diluted by mixing 51 gallons of EDS-ER™, 5 liters of SDC-9™ and 143 pounds of nutrients with approximately 2,304 gallons of water to achieve the desired treatment volume for each injection point as shown on the treatment area calculation sheet in **Appendix A**. Approximately 9,420 gallons of dilute EDS-ER™ mixture will be injected into 6 injection points in the vicinity of 50WW12 shown on **Figure 3-1**. The exact quantity of buffer (sodium bicarbonate) will be based on results of the buffer capacity test.

The aquifer treatment demand in the vicinity of 50WW13 based on EOS's 60% carbon product is 8,465 pounds (**Appendix A**). That is equivalent to 5,079 pounds of 100% carbon EDS-ER™. The gallons concentrated solution of EDS-ER™ will be diluted by mixing 110 gallons of EDS-ER™, 12 liters of SDC-9™ and 308 pounds of nutrients with approximately 4,990 gallons of water to achieve the desired treatment volume for each injection point as shown on the treatment area calculation sheet in **Appendix A**. Approximately 30,618 gallons of dilute EDS–ER™ mixture will be injected into 6 injection points in the vicinity of 50WW13 shown on **Figure 3-1**. The exact quantity of buffer (sodium bicarbonate) will be based on results of the buffer capacity test.

3.5 Bioaugmentation Culture Loading

Bioaugmentation will involve adding SDC-9™ to the amendment solution containing EDS-ER™. The EDS–ER™ will provide sufficient "food source" as the dechlorinating culture (SDC-9™) enters the subsurface environment.

An additional nutrient (DAP) and buffer (sodium bicarbonate) will be added to maintain a neutral pH in the injection area which is essential for the dechlorinating culture to thrive.

3.6 Performance Monitoring

Performance monitoring at eight locations will be used to evaluate the effectiveness of the ISB treatment. Following the injection event, groundwater will be monitored quarterly for two years.

3.6.1 Baseline Groundwater Monitoring

A separate baseline sampling event will not be conducted prior to implementing the contingency remedy. Sampling results from the November 2019 RA-O event will be used as baseline data. The RA-O samples will be analyzed for perchlorate, VOCs, total organic carbon, dissolved gases (ethene, ethane and methane), carbon dioxide, and ferrous iron (field only). Additionally, field parameters like DO, oxidation-reduction potential (ORP), specific conductance, temperature and pH will also be collected. The baseline sampling results will be compared to sample results from post-ISB performance monitoring for remedy effectiveness evaluation.

3.6.2 In-Situ Bioremediation Performance Monitoring

Groundwater monitoring will be performed for eight quarterly events following implementation of ISB to demonstrate effectiveness of the ISB remedy. A total of eight wells will be included in the performance monitoring program. Wells included in the ISB performance monitoring program and analytical parameters are shown in **Table 3-1**. These wells were selected for their placement relative to the treatment area to monitor effectiveness of ISB. Other monitoring wells will continue to be sampled on an annual basis as part of the RA-O/LTM network included in **Table 3-2**.

This page intentionally left blank.

4.0 IN-SITU BIOREMEDIATION WORK PLAN

ISB will be conducted at LHAAP-50 to remediate groundwater impacted with perchlorate and VOCs. The plume geometry and proposed injections have been developed using the basis and details of the RD in **Section 3.0**. The specific formulation of EVO used to develop the RAWP is EDS–ER™ (**Appendix B**). If EDS–ER™ is not available at the time the injections are ready to proceed, equivalent EVO product will be used, and the volumes of EVO will be adjusted if the EVO content is less than the 100% in EDS–ER™. Details of the pre-mobilization, mobilization, injection, and demobilization field activities are provided in the following sections.

4.1 In-Situ Bioremediation Injection Plan

To treat the perchlorate and VOCs impacted groundwater in the shallow groundwater aquifer, a biogrid will be installed by injecting EDS–ER™ or an equivalent EVO product, SDC-9™, and nutrients, into 12 DPT points as shown in **Figure 3-1**. **Table 4-1** specifies the volume of amendment mixture to be injected and the proposed injection interval for each injection point.

4.2 Pre-Mobilization Activities

4.2.1 Permitting

No permitting is required prior to the commencement of field work.

4.2.2 Notification

TCEQ and USEPA will be notified two weeks in advance of commencement of fieldwork activities.

4.2.3 Utility Clearance

Utility location and clearance for intrusive activities will be conducted prior to drilling as follows:

The site health and safety officer will:

- Prepare a map indicating the area(s) where intrusive activity is planned to occur.
- Perform the necessary reviews.
- Contact the Texas Excavation Safety System, Inc. utility notification service by calling 811 or 800 892 0123 or using their online submittal system. This notification is to be made a minimum of three working days prior to the initiation of intrusive activity (excluding Saturdays, Sundays, and holidays), but not greater than 14 days.

- Verify that all underground installations have been located, physically marked, and then noted on the map. If needed, a third-party location service will be used.
- Mark all overhead utilities with kilovolts rating on the map. It is not anticipated that the existing overhead lines will impact the proposed injection location layout.
- Notify the appropriate agencies, contracting officer's representative, and property owners (when applicable).
- Confirm that utility clearance is complete and documented.

A safety meeting shall be held, and a job safety analysis shall be completed by all personnel who are involved in the intrusive activities prior to initiating work.

4.3 Site Activities

Once the premobilization activities are completed, the field crew, DPT crew, and injection equipment will mobilize to the site to perform the following activities.

4.3.1 Baseline Sampling

A separate baseline sampling event will not be conducted prior to implementing the contingency remedy. Sampling results from the RA-O event conducted in November 2019 will be used for baseline sampling. The baseline sampling results will be compared to sample results collected post ISB injections. The newly installed well 50WW29 was sampled in August 2019, and the results are included in **Table 2-2**. 50WW29 has been added to the ISB performance monitoring network in **Table 3-1** and to the LTM network as shown **Table 3-2**.

4.3.2 Injection Activities

1. Mobilize materials, equipment, mixing tanks, and labor for injections
2. Set up traffic signage and controls as needed
3. Layout injection locations and clear DPT injection points (**Section 4.3.6.1**)
4. Core concrete/asphalt at injection points, if needed, and adjust any points if obstructions are found and push rods to the desired injection interval (**Section 4.3.4**)
5. Setup amendment, equipment, and materials onsite
6. Begin preparing amendment solution for injection a day before planned injections. Preparation of amendment solution will be a continual activity (**Section 4.3.6.2**)
7. Record injection intervals and volumes during injections (**Appendix C**)

8. Once injection is complete at a DPT injection point, abandon point (**Section 4.3.4**)
9. Record DPT injection point locations with global positioning system (GPS)

4.3.3 Post-Injection Activities

After injections, the site will be restored as needed and the injection personnel and equipment will be demobilized. Groundwater sampling and reporting will be conducted as described in **Section 5.0**.

4.3.4 Direct-Push Technology Drilling

Drilling will utilize DPT rigs for in situ injections through a probe with a 4-foot injection screen interval. The injections will be performed in two areas in the vicinity of wells 50WW12 and 50WW11/50WW13 over a treatment thickness of 18-feet and 42-feet, respectively. Injections will be conducted using a top down or bottom up approach, depending on lithology and field conditions. The injection depth intervals will be adjusted to best treat the saturated zone identified in the nearest monitoring wells or soil boring where lithology was recorded (**Table 4-1**). A total of 12 points will be installed using a DPT rig in accordance with the procedures presented in the Installation-Wide Work Plan (IWWP) (Bhate 2018c). Each DPT point will be abandoned by filling with grout after injections are completed.

4.3.5 In-Situ Bioremediation Injection

Placement of DPT points is shown on **Figure 3-1**. **Table 4-1** provides the number of injection points, target depths, volumes of each amendment to be prepared, and target volumes to be injected. The calculations to determine the required volumes are based on the calculation sheets provided in **Appendix A**.

4.3.6 Preparation

4.3.6.1 Location Preparation

Prior to the ISB injection, the site will be cleared of aboveground hazards. A GPS device or linear measurements from monitoring wells and other site features will be used to locate each injection point. The locations will be reviewed to confirm that there are no injection points that will impact any underground or above ground utilities. Additionally, the locations will be reviewed to determine if concrete coring is needed at a location. If the concrete is too thick to core at a location, the location will be adjusted as needed. If there are points that are affected by utility locations, the plan will be altered to relocate those points to avoid the utility, while still meeting the injection objectives. The final DPT injection point locations will be recorded with the GPS. Prior to drilling with the DPT at each point, the location will be excavated with a hand auger or post-hole digger to 5 feet to check for underground obstructions/utilities unless the location has been cleared by other means and an exemption authorized.

4.3.6.2 Amendment Preparation

There are various EVO formulations commercially available in the market. EDS–ER™ or an equivalent product will be used for injections. The ISB amendments will be prepared in mixing tanks. The tanks will be located at LHAAP-50 adjacent to the injection area or at another convenient location. The amendment solution will be mixed prior to the day of injection. The potable water required for mixing will be obtained from water supply well near the fire station or from an off-base fire hydrant, and transported to the mixing tank in a water truck.

Steps required for preparation of ISB amendments are as follows:

- Approximately 24 hours prior to injection, the anaerobic solution will be prepared by adding the required volume of EVO, dilution water, and nutrients into the mixing tank. The same EVO amendment mixture is used for all injection locations. Microbes in the water will grow on a small amount of the carbon, and during respiration, they will use the available oxygen in the mixing tank, creating an anaerobic medium.
- When the solution has become anaerobic, based upon a DO meter reading of less than 1.0 milligrams per liter, SDC-9™ will be added and the amendments will be injected. The amendment solution will be injected into the subsurface using an injection system, as shown on **Figure 4-1**.
- The injection volume for each point at an injection area along with the associated mass and volume of amendment are provided in **Table 4-1** and are based on 100% EVO oil by weight.

4.3.7 In-Situ Injections

4.3.7.1 Injection System

An injection system will be used to allow for multiple DPT injections at a single time under low pressure (i.e., less than 40 psi). The injection system will include volume and pressure gauges, so amendment volume can be recorded for each injection location. The total volumes per well, injection pressures and gallon per minute will be tracked on paper and electronically using the Injection Log in **Appendix C**. The injection system will be connected to each DPT probe using hoses as shown in the schematic on **Figure 4-1**.

4.3.7.2 Monitoring During Injections

During the ISB injections, possible amendment surfacing (also called daylighting) may occur at the ground surface and will be monitored visually. Injection pressures will also be monitored since sudden reductions may be an indication of amendment loss into subsurface, possibly from fracturing induced by the injection or from a high-permeability zone. If daylighting on the surface is observed, injection rates will be reduced. If the reduction in pressure does not eliminate the daylighting, injections will be shut down and the remaining injection volume will be divided among the nearest injection locations to ensure the full design volume is injected in the area. Goose Prairie Creek will be monitored during and after injections for decrease in DO and visual changes in water color along the creek. Additional monitoring and visual observations will be conducted to determine if any decrease in DO is from injection materials or changes in environmental conditions. If daylighting into a surface water feature is observed, the injection at that location will cease and necessary measures to capture the fluid released and to maintain the DO levels in the surface water will be implemented, if necessary. The remaining volume will be distributed to the other nearby injection locations.

4.3.8 Remediation Derived Waste Management

Remediation derived waste includes the following:

- Groundwater generated from purging of wells prior to sampling
- Decontamination fluids
- Disposable protective clothing and supplies

Wastewater generated from equipment decontamination, well development, groundwater sampling, or other investigative and remedial activities will be stored in 55-gallon drums and transported to the groundwater treatment plant at LHAAP-18/24 as specified in Section 3.8.2 of the IWWP (Bhate 2018c).

This page intentionally left blank.

5.0 POST-REMEDIAL MONITORING AND REPORTING

5.1 Groundwater Sampling

Groundwater sampling events will consist of:

- Baseline sampling: November 2019 RA-O event will be considered the baseline sampling event.
- Quarterly performance monitoring for two years used to evaluate the performance of the contingency remedy (**Table 3-1**).
- LTM to be conducted annually until the groundwater perchlorate and VOC concentrations are below the MCL/PCL or the regulators agree that a less frequent sampling schedule is more appropriate (**Table 3-2**).

5.1.1 Baseline Sampling

The RA-O sampling event conducted in November 2019 will be considered the baseline sampling event. The baseline sampling event will help establish baseline conditions against which the remedial performance will be evaluated.

5.1.2 Performance Monitoring Year 1 and Year 2

Wells included in **Table 3-1** will be used to monitor the performance of ISB injections as shown in **Figure 5-1**. The process of biodegradation results in depletion of DO and ORP. Performance monitoring will be conducted to evaluate change in geochemical conditions and perchlorate/VOCs concentrations. For the first two years post-injection, the ISB performance monitoring wells will be sampled quarterly, with results provided at the monthly manager's meetings and summarized more fully in the Annual RA-O reports described in **Section 5.3**.

5.1.3 Long-Term Monitoring

The annual LTM will continue for wells and analytical parameters shown in **Table 3-2**. The number of LTM wells and analytical parameters may be reduced based on the performance monitoring results and recommendations made in RA-O Reports. Monitoring will be discontinued with regulator concurrence after perchlorate/VOCs concentrations in the wells in the treatment area drop below the MCL/PCL. The need for any additional LTM will be discussed in the next Five-Year Review.

5.2 Response Action Completion Report Addendum

A RACR Addendum will be submitted upon implementation of the contingency remedy. ISB performance monitoring and LTM results will be included in Annual RA-O Reports.

5.3 Annual Remedial Action Operation Reports

RA-O Reports will continue to be submitted on an annual basis based on the current schedule. The RA-O report will include results from the RA-O/LTM and performance monitoring events. The reports will include an evaluation of the effectiveness of the contingency remedy for LHAAP-50. Wells within the plume areas will be evaluated for effectiveness of treatment and wells surrounding the plume will be used to evaluate plume stability. The report will provide recommendations if possible for reducing the number of monitoring wells to be included in the monitoring program and/or frequency of monitoring events. The Annual RA-O Report will also include the annual LUC inspection, and monitoring system operation and maintenance discussion.

5.3.1 Remedy Evaluation

Remedial performance will be evaluated using two primary lines of evidence to determine if the remedy is operating properly:

- Plume stability (i.e., plume concentrations are declining in the performance wells, and the plume is not expanding in area as demonstrated by downgradient monitoring wells)
- Reducing conditions conducive for the degradation of perchlorate/VOCs are present within the treatment area

Follow-up injections may be needed if the remedy is determined to not be performing, although reinjections are not expected to be needed within the 3- to 5-year lifespan of the EVO mixture selected. Nonetheless, the decision for reapplication of organic carbon will be made based on performance monitoring results. Proposed performance monitoring network locations and analyses are shown in **Table 3-1**.

6.0 SCHEDULE

Table 6-1 shows the estimated duration for each major site activity and timeline. Weather and unknown site conditions could affect this schedule.

This page intentionally left blank.

7.0 REFERENCES

AECOM Technical Services, Inc. (AECOM). 2013. *Final Remedial Action Work Plan, LHAAP-50, Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas*. June.

AECOM. 2016. *Final Remedial Action Completion Report, LHAAP-50, Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas*. June.

Bhate Environmental, Inc. (Bhate). 2018a. *Draft Final Third Annual Remedial Action Operation Report, LHAAP-50, Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas*. July.

Bhate. 2018b. *Final Fourth Annual Remedial Action Operation Report, LHAAP-50, Former Sump Water Tank, Longhorn Army Ammunition Plant, Karnack, Texas*. December.

Bhate. 2018c. *Draft Final Installation-Wide Work Plan*, *Longhorn Army Ammunition Plant, Karnack, Texas*. March.

Bhate. 2019. *Draft Explanation of Significant Differences, Record of Decision Dated September 2010, Contingency Remedy at LHAAP-50, Former Sump Water Tank, Longhorn Army Ammunition Plant*. April.

Jacobs Engineering Group, Inc. (Jacobs). 2002. *Final Remedial Investigation Report for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50, and 60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas*. January.

Shaw Environmental & Infrastructure, Inc. (Shaw). 2011. *Final Remedial Design, LHAAP-50, Former Sump Water Tank, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas*. September.

U.S. Army Corps of Engineers (USACE). 2019. *Draft Five-Year Review Report for Longhorn Army Ammunition Plant, Town of Karnack, Harrison County, Texas*. February.

USACE. 2010. *Record of Decision, LHAAP-50, Former Sump Water Tank, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas*. September.

U.S. Environmental Protection Agency (USEPA). 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. EPA/600/R-98/128. September.

This page intentionally left blank.

Tables

Table 1-1
Groundwater Cleanup Levels, LHAAP-50

Chemical	Concentration (µg/L)	Basis
Perchlorate	17	PCL
Trichloroethene	5	MCL
cis-1,2-Dichloroethene	70	MCL
Vinyl chloride	2	MCL
1,1-Dichloroethene	7	MCL
1,2-Dichloroethane	5	MCL
Tetrachloroethene	5	MCL

Notes:

µg/L - micrograms per liter

MCL - maximum contaminant level

PCL - Texas residential groundwater protective concentration level

Table 2-1
Monitoring Well Construction Summary, LHAAP-50

Well ID	Aquifer	Northing [a]	Easting [a]	Ground Surface Elevation [b,c]	Top of Casing Elevation [b]	Well Depth (ft bgs) [c]	Screen Interval (ft bgs) [c]	
							Top	Bottom
50WW01	Upper Shallow	6957599.96	3309311.00	195.29	198.5	20	10	20
50WW02	Upper Shallow	6957436.64	3309569.44	197.4	200.74	19	9	19
50WW03	Upper Shallow	6957162.82	3309376.10	199.88	202.94	20	10	20
50WW04	Upper Shallow	6957156.94	3309947.41	201.64	204.51	20	10	20
50WW05	Upper Shallow	6957581.45	3309709.69	195.34	197.6758	23	15	25
50WW06	Lower Shallow	6957553.93	3309790.22	192.99	195.3462	58	45	55
50WW07	Upper Shallow	6957484.78	3310408.51	199.88	202.55	29	19	29
50WW08	Upper Shallow	6957434.02	3309606.40	197.16	199.67	29.75	15	29
50WW09	Lower Shallow	6957437.22	3309602.73	197.06	199.41	59.5	44	59
50WW10	Intermediate	6957441.16	3309598.97	196.72	199.25	109	99	108
50WW11	Upper Shallow	6957527.87	3309743.98	194.72	197.07	35.3	20	35
50WW12	Upper Shallow	6957569.82	3309877.05	193.26	195.66	35.2	20	35
50WW13	Upper Shallow	6957493.69	3309707.59	195.01	197.45	35.1	20	35
50WW14	Lower Shallow	6957496.69	3309711.32	195.14	197.52	58.5	43	58
50WW15	Upper Shallow	6957551.18	3309588.29	193.95	196.3	35	20	34
50WW16	Upper Shallow	6957700.27	3309748.81	194.1	196.66	35.2	20	35
50WW17	Fully Screened Shallow	6957793.28	3310264.87	192.73	195.13	65	20	64
50WW18	Upper Shallow	6957788.94	3310128.27	192.57	194.84	35.2	20	35
50WW19	Fully Screened Shallow	6957748.65	3310322.10	193.71	195.96	64.2	19	64
50WW20	Fully Screened Shallow	6957347.68	3310050.11	200.3	202.54	53.3	18	53
50WW21	Upper Shallow	6957364.34	3309866.89	197.68	200.14	35	20	34
50WW22	Upper Shallow	6957340.07	3309634.58	199.93	202.1	35	20	34
50WW23	Upper Shallow	6957444.94	3309984.90	198.33	200.75	35.1	20	35
50WW24	Upper Shallow	6957469.14	3310101.17	199.37	201.63	35.5	20	35
50WW25	Lower Shallow	6957715.54	3309528.56	193.48	196	55	NA	NA
50WW26	Lower Shallow	6957367.75	3309864.01	197.68	200.07	60.2	45	60
50WW27	Lower Shallow	6957556.13	3309590.81	193.84	196.22	58	43	57
50WW28	Upper Shallow	6963745.19	3306303.59	205.57	194.71	24.3	27	37

Notes:

[a] Northing and Easting Coordinates are Texas State Plane Coordinate System, North Central Zone (4202), 1983 North American Datum (NAD 83).

[b] Survey elevations are North American Vertical Datum of 1988 (NAVD 88).

[c] The ground surface elevation is measured at the soil surface adjacent to the well pad.

ft - feet

ID - identification

TOC - top of casing

Table 2-2
LHAAP-50 Sampling Results for Newly-Installed Well 50WW29

		Location Code	50WW29	
		Sample ID	50WW29-190815	
		Sample Date	8/15/2019	
		Sample Purpose	REG	
Parameter	Units	MCL / GW-Ind / PCL	Result	Val Qual
Perchlorate (Method SW6850)				
Perchlorate	µg/L	17	< 2	U
Volatiles (Method SW8260)				
1,1,1,2-Tetrachloroethane	µg/L	110	< 0.5	U
1,1,1-Trichloroethane	µg/L	200	< 0.5	U
1,1,2,2-Tetrachloroethane	µg/L	14	< 0.5	U
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	3,100,000	< 0.5	U
1,1,2-Trichloroethane	µg/L	5	< 0.5	U
1,1-Dichloroethane	µg/L	10,000	< 0.5	U
1,1-Dichloroethene	µg/L	7	< 0.5	U
1,1-Dichloropropene	µg/L	2.9	< 0.5	U
1,2,3-Trichlorobenzene	µg/L	310	< 0.5	U
1,2,3-Trichloropropane	µg/L	0.041	< 0.5	U
1,2,4-Trichlorobenzene	µg/L	70	< 0.5	U
1,2,4-Trimethylbenzene	µg/L	5,100	< 0.5	U
1,2-Dibromo-3-chloropropane	µg/L	0.2	< 0.5	U
1,2-Dibromoethane	µg/L	0.05	< 0.5	U
1,2-Dichlorobenzene	µg/L	600	< 0.5	U
1,2-Dichloroethane	µg/L	5	< 0.5	U
1,2-Dichloropropane	µg/L	5	< 0.5	U
1,3,5-Trimethylbenzene	µg/L	5,100	< 0.5	U
1,3-Dichlorobenzene	µg/L	3,100	< 0.5	U
1,3-Dichloropropane	µg/L	29	< 0.5	U
1,4-Dichlorobenzene	µg/L	75	< 0.5	U
2,2-Dichloropropane	µg/L	42	< 0.5	U
2-Butanone	µg/L	61,000	< 1	U
2-Chlorotoluene	µg/L	2,000	< 0.5	U
2-Hexanone	µg/L	6,100	< 1	U
4-Chlorotoluene	µg/L	2,000	< 0.5	U
Acetone	µg/L	92,000	< 1	U
Benzene	µg/L	5	< 0.5	U
Bromobenzene	µg/L	2,000	< 0.5	U
Bromochloromethane	µg/L	4,100	< 0.5	U
Bromodichloromethane	µg/L	4.6	< 0.5	U
Bromoform	µg/L	36	< 0.5	U
Bromomethane	µg/L	140	< 0.5	U
Carbon disulfide	µg/L	10,000	< 1	U
Carbon tetrachloride	µg/L	5	< 0.5	U
Chlorobenzene	µg/L	100	< 0.5	U
Chloroethane	µg/L	41,000	< 0.5	U
Chloroform	µg/L	1,000	< 0.5	U

Table 2-2
LHAAP-50 Sampling Results for Newly-Installed Well 50WW29

		Location Code	50WW29	
		Sample ID	50WW29-190815	
		Sample Date	8/15/2019	
		Sample Purpose	REG	
Parameter	Units	MCL / GW-Ind / PCL	Result	Val Qual
Chloromethane	µg/L	220	< 0.5	U
cis-1,2-Dichloroethene	µg/L	70	< 0.5	U
cis-1,3-Dichloropropene	µg/L	5.3	< 0.5	U
Dibromochloromethane	µg/L	34	< 0.5	U
Dibromomethane	µg/L	380	< 0.5	U
Dichlorodifluoromethane	µg/L	20,000	< 0.5	U
Ethylbenzene	µg/L	700	< 0.5	U
Hexachlorobutadiene	µg/L	20	< 1	U
Isopropylbenzene	µg/L	10,000	< 0.5	U
m,p-Xylenes	µg/L	10,000	< 1	U
Methyl isobutyl ketone	µg/L	8,200	< 1	U
Methylene chloride	µg/L	5	< 1	U
Naphthalene	µg/L	2,000	< 0.5	U
n-Butylbenzene	µg/L	4,100	< 0.5	U
n-Propylbenzene	µg/L	4,100	< 0.5	U
o-Xylene	µg/L	10,000	< 0.5	U
p-Isopropyltoluene	µg/L	10,000	< 0.5	U
sec-Butylbenzene	µg/L	4,100	< 0.5	U
Styrene	µg/L	100	< 0.5	U
tert-Butylbenzene	µg/L	4,100	< 0.5	U
Tetrachloroethene	µg/L	5	< 0.5	U
Toluene	µg/L	1,000	< 0.5	U
trans-1,2-Dichloroethene	µg/L	100	< 0.5	U
trans-1,3-Dichloropropene	µg/L	29	< 0.5	U
Trichloroethene	µg/L	5	0.65	J
Trichlorofluoromethane	µg/L	31,000	< 0.5	U
Vinyl chloride	µg/L	2	< 0.5	U

Notes:

µg/L - micrograms per liter

J - estimated value; analyte concentration was less than the limit of quantification

U - analyte was not detected

COC - contaminants of concern

GW-Ind - groundwater medium-specific concentration for industrial use

MCL - maximum contaminant level

MSC - medium-specific concentrations

NA - not analyzed

PCL - Texas residential groundwater protective concentration level

REG - regular sample

Val Qual - validation qualifier

Table 3-1
ISB Performance Monitoring Network Locations and Analyses

Monitoring Location	Primary Rationale for Well Selection	Proposed Analyses: Performance – Years 1 and 2 (Quarterly)								
		Perchlorate (SW6850)	VOCs (SW8260)	DO (field reading)	ORP (field reading)	pH (field reading)	Ferrous Iron (field reading)	Anions (SW9056)	Diss Gases (ethene, ethane, methane & carbon dioxide) (RSK175)	TOC (SM5310C)
50WW08	Upgradient well	✓	✓	✓	✓	✓				
50WW05	Crossgradient well	✓	✓	✓	✓	✓				
50WW06	Performance data within the plume	✓	✓	✓	✓	✓	✓	✓	✓	✓
50WW11	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓
50WW12	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓
50WW13	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓
50WW14	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓
50WW29	Downgradient well	✓	✓	✓	✓	✓				

Notes:

Anions include chloride, nitrate, and sulfate.

✓ Indicates that sample will be collected and analyzed for the listed analyte.

Table 3-2
RA-O / Long-Term Monitoring Network, LHAAP-50

Well ID	VOCs (Method SW 8260)	Perchlorate (Method SW6850)	Field Parameters	TOC (Method SM5310C)	Anions (chloride, nitrate, sulfate) (Method SW9056)	Dissolved Gases (ethene, ethane, methane) (Method RSK175)	Carbon dioxide (Method RSK175)	Ferrous Iron (only field)
Groundwater Sample Locations								
50WW08	x	x	x					
50WW11	x	x	x	x	x	x	x	x
50WW12	x	x	x	x	x	x	x	x
50WW13	x	x	x	x	x	x	x	x
50WW15	x	x	x					
50WW16	x	x	x					
50WW18	x	x	x					
50WW22	x	x	x					
50WW23	x	x	x					
50WW05	x	x	x					
50WW06	x	x	x	x	x	x	x	x
50WW09	x	x	x					
50WW14	x	x	x	x	x	x	x	x
50WW29	x	x	x					

Notes:

The RA-O results from the Nov 2019 sampling event will be used for baseline sampling event.

Field Parameters: DO, ORP, pH, specific conductivity, temperature

ID - identification

DO - dissolved oxygen

ORP - oxidation reduction potential

RA-O - remedial action operation

TOC - total organic carbon

VOCs - volatile organic compounds

Table 4-1
Injection Locations and Amendment Volumes

DPT Location	Amendment Volume per Location						DPT Injection Depths (ft bgs) [a]	Nearest Monitoring Well	Lithology (ft bgs)
	Gallons of EVO (EDS-ER™ or Equivalent)	Liters of SDC-9™ (1.0E11)	Pounds of Nutrients (DAP)	Pounds of Buffer (sodium bicarbonate)	Gallons of Water	Total Injection Volume (gallons)			
50DPT01	110	12	308	37	4,990	5,103	18 - 60	50WW14	0 - 2 ft bgs: Silty fine sand 2 - 15 ft bgs: Silty clay 15 - 30 ft bgs: Silty fine sand 30 - 61.5 ft bgs: Poorly graded sand with silt 58.5 ft bgs: Bottom of well casing
50DPT02	110	12	308	37	4,990	5,103	18 - 60		
50DPT03	110	12	308	37	4,990	5,103	18 - 60		
50DPT04	110	12	308	37	4,990	5,103	18 - 60		
50DPT05	110	12	308	37	4,990	5,103	18 - 60		
50DPT06	110	12	308	37	4,990	5,103	18 - 60		
50DPT07	48	5	132	16	2,139	2,188	17 - 35	50WW12	0 - 2 ft bgs: Silt 2 - 10 ft bgs: Lean clay with sand 10 - 35 ft bgs: Poorly graded sand
50DPT08	48	5	132	16	2,139	2,188	17 - 35		
50DPT09	48	5	132	16	2,139	2,188	17 - 35		
50DPT10	48	5	132	16	2,139	2,188	17 - 35		
50DPT11	48	5	132	16	2,139	2,188	17 - 35		
50DPT12	48	5	132	16	2,139	2,188	17 - 35		

Notes:

Table will be updated with quantities of buffer (Sodium Bicarbonate) which will be determined based on buffer capacity tests.

[a] The DPT injection depths may be altered in the field depending on lithology.

DAP - Diammonium Phosphate

DPT - direct-push technology

EDS-ER™ - electron donor solution-extended release

EVO - emulsified vegetable oil

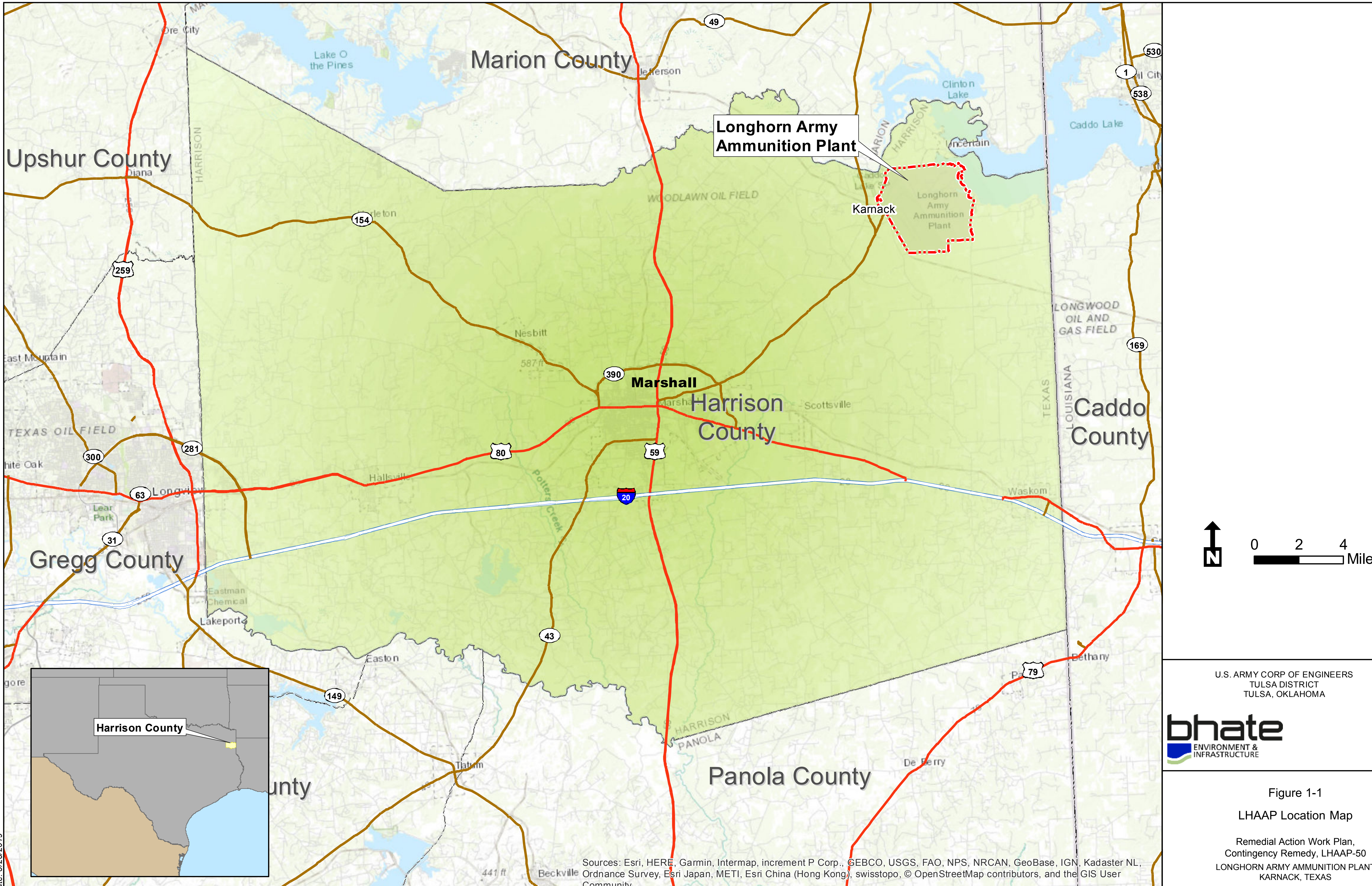
ft bgs - feet below ground surface

SDC-9™ - APTIM's dechlorinating culture

Table 6-1
Schedule of Major Site Activities

Activities	Duration
Provide Injection Information to State	30
Utility Clearance	1
Mobilization / Site Set-up for Injections	1
Clear Injection Locations	2
Conduct Injection	15
Demobilization	1
Total Number of Days	**50**

Figures



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Date: 5/28/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP_LocationMap.mxd

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

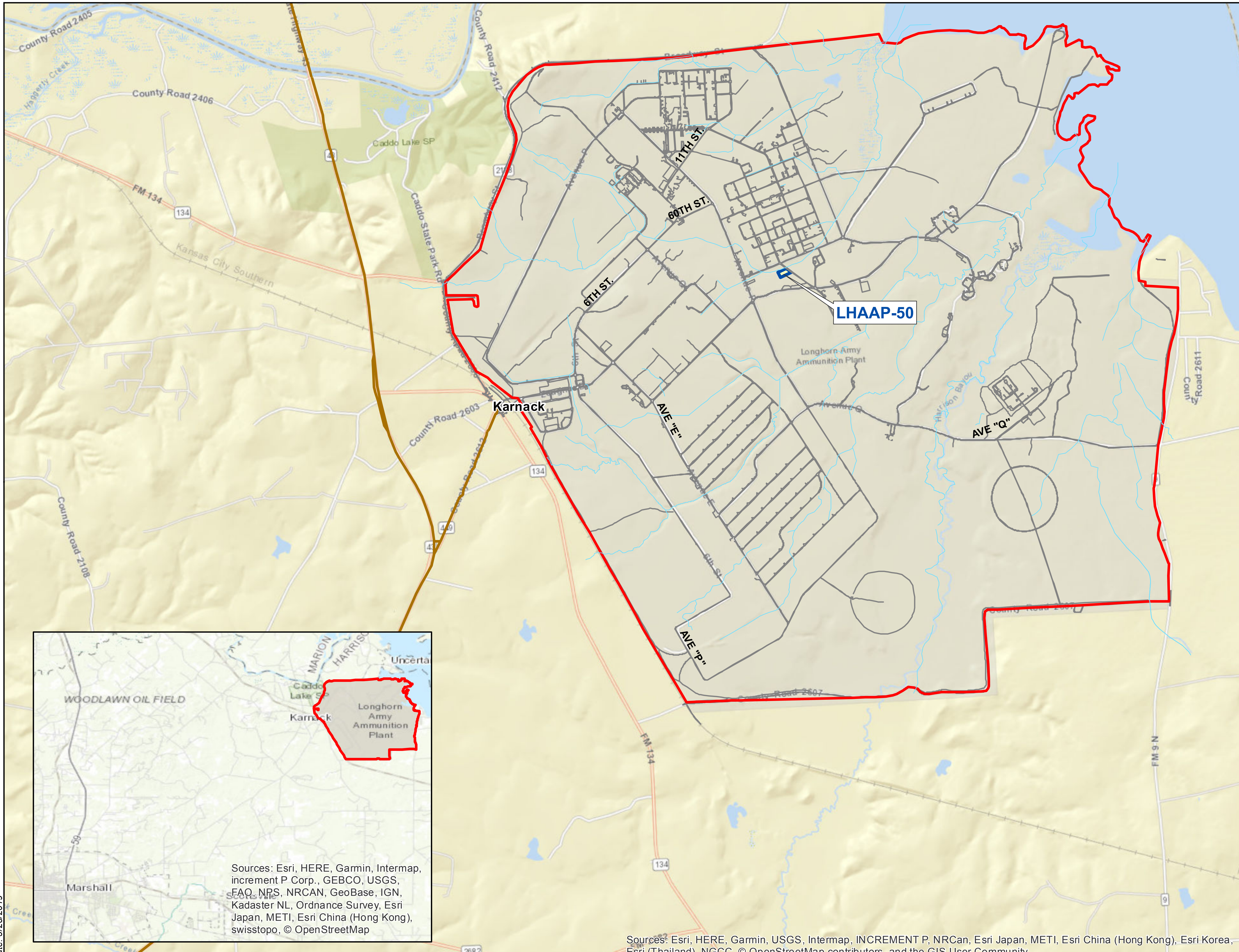
bhate ENVIRONMENT & INFRASTRUCTURE

APTIM

Figure 1-1

LHAAP Location Map

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



Stream
Road
LHAAP Boundary
LHAAP-16 Site Boundary

N

0 1,500 3,000 Feet

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

bhate ENVIRONMENT & INFRASTRUCTURE

APTIM

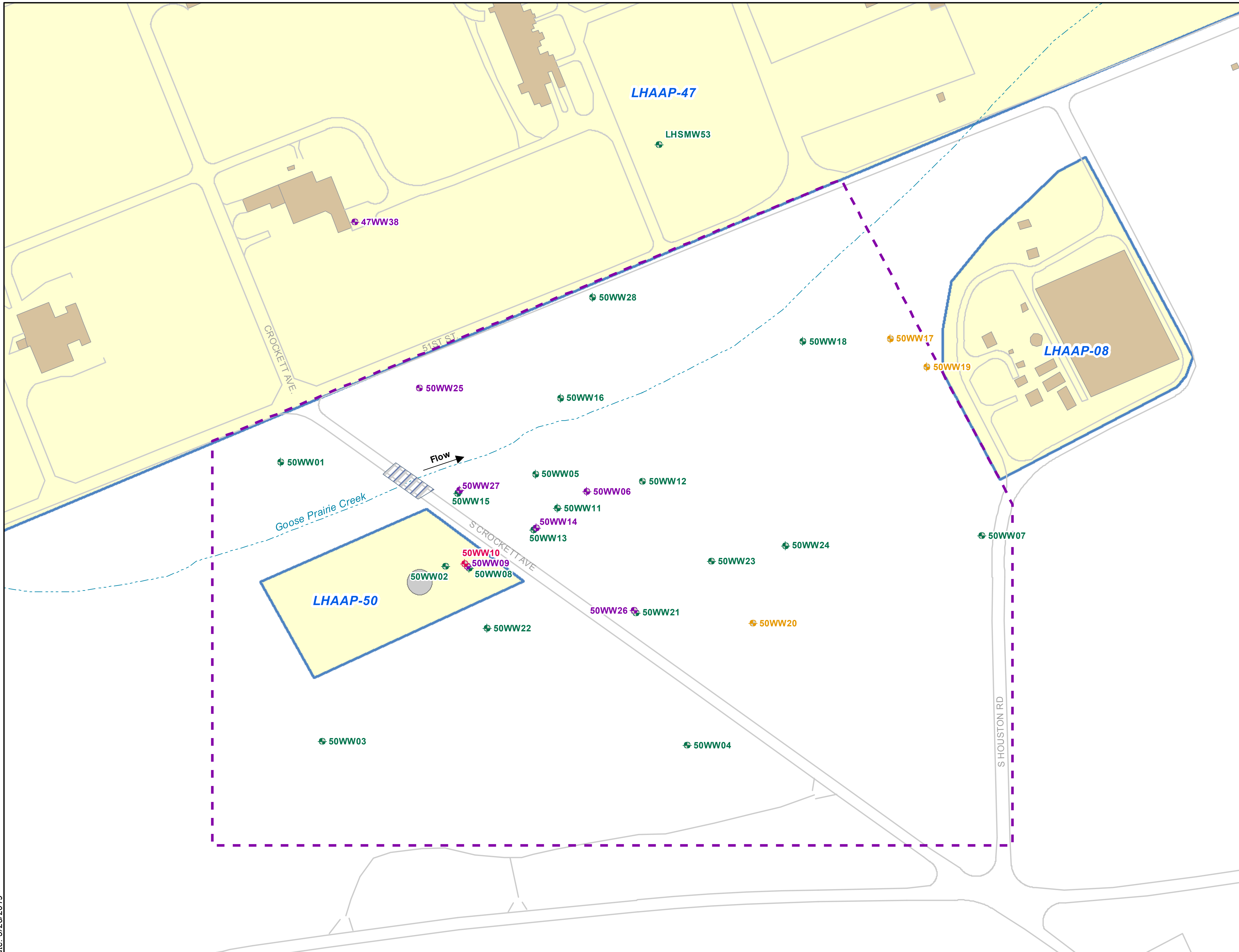
Figure 1-2

LHAAP Site Location Map

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 5/28/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP50_SiteLocationMap.mxd



Lower Shallow Monitor Well
Upper Shallow Monitor Well
Fully Penetrating Shallow Monitor Well
Intermediate Monitor Well
Goose Prairie Creek
Roads
Land Use Control Boundary
Bridges
Former Storage Tank Location
Buildings
Site Boundaries

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

bhate ENVIRONMENT & INFRASTRUCTURE

APTIM

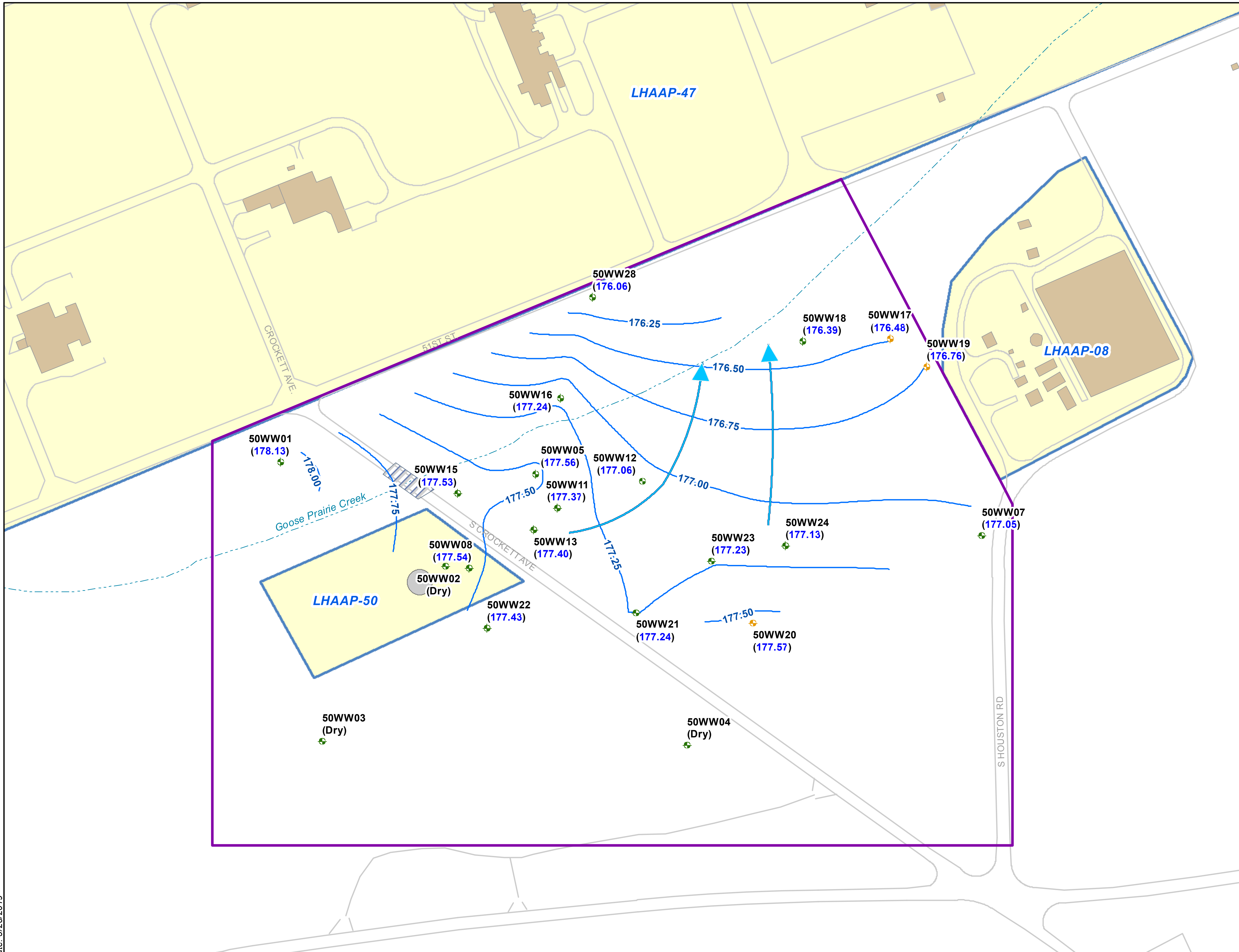
Figure 1-3
Land Use Control Boundary

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 5/28/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP50_LUC.mxd



Upper Shallow Monitoring Well
Fully Screened Shallow Monitor Well
Groundwater Flow Direction
Groundwater Contour
Land Use Control Boundary
Bridges
Former Storage Tank Location
Goose Prairie Creek
Roads
Buildings
Site Boundaries

Note:
1. Monitor wells 50WW02, 50WW03, and 50WW04 were dry during Nov 2017 sampling.
2. Groundwater levels (175.2) are in feet above mean sea level (ft amsl).

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

bhate ENVIRONMENT & INFRASTRUCTURE

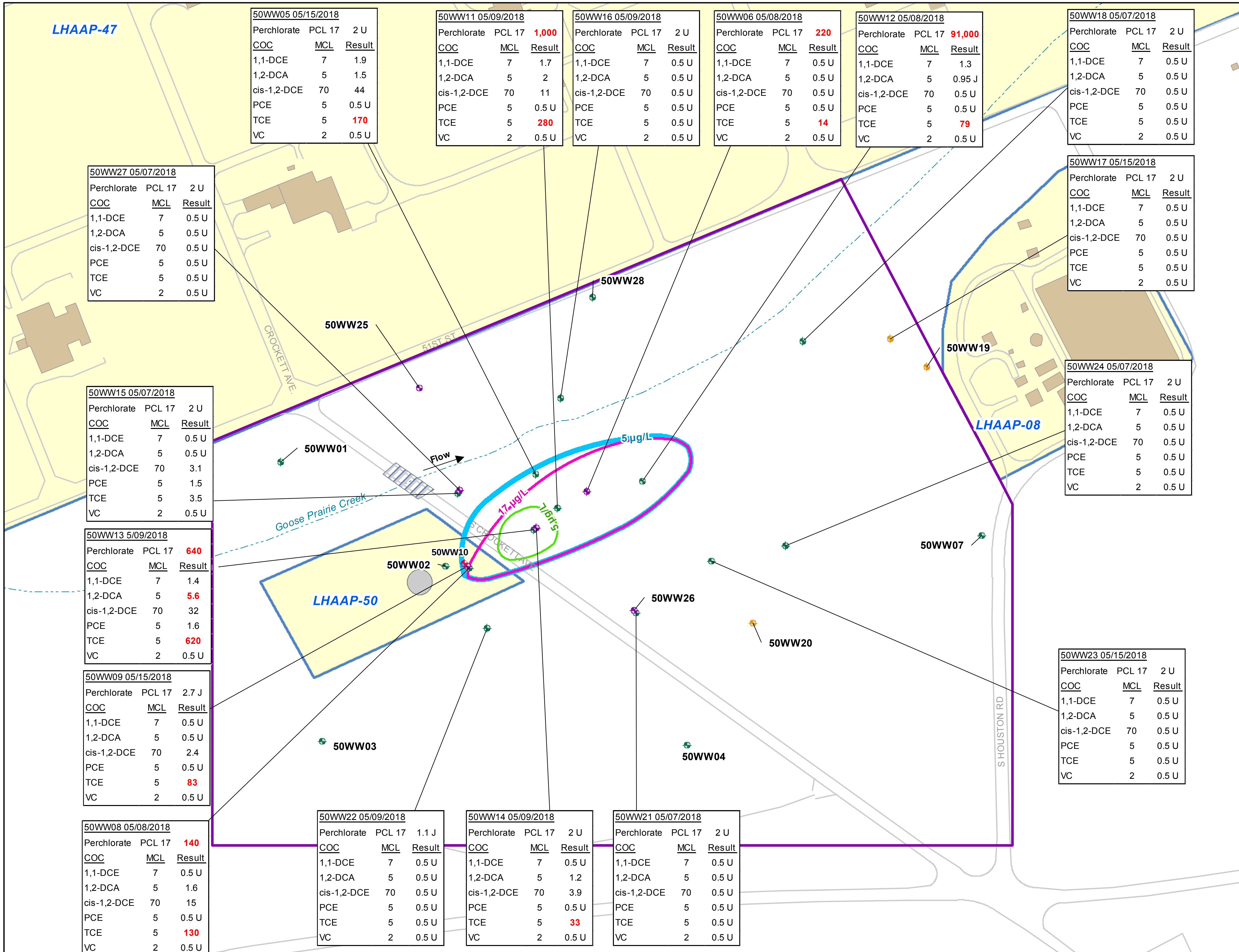
APTIM

Figure 1-4
Potentiometric Surface Map for the Shallow Zone, May 2018

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 5/28/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP50_ShallowZoneMay2018_GW.mxd



- Lower Shallow Monitoring Well
- Upper Shallow Monitoring Well
- Fully Penetrating Shallow Monitoring Well
- Intermediate Monitoring Well
- 1,2-DCA Contour
- Perchlorate Contour (*Dashed where inferred*)
- TCE Contour
- Goose Prairie Creek
- Roads
- Land Use Control Boundary
- Bridges
- Former Storage Tank Location
- Buildings
- Site Boundaries

Notes:
1. All concentrations are shown in micrograms per liter (µg/L).
2. 1,1-DCE = 1,1-dichlorothene
   1,2-DCA = 1,2-dichlorethane
   cis-1,2-DCE = cis-1,2-dichloroethene
   PCE = tetrachloroethene
   TCE = trichloroethene
   VC = vinyl chloride
   MCL = maximum concentration level
   PCL = protective concentration level
   U = below detection limit
   J = estimated value
   COC = contaminant of concern
3. Results in red are above the MCL or PCL.

0 75 150 Feet

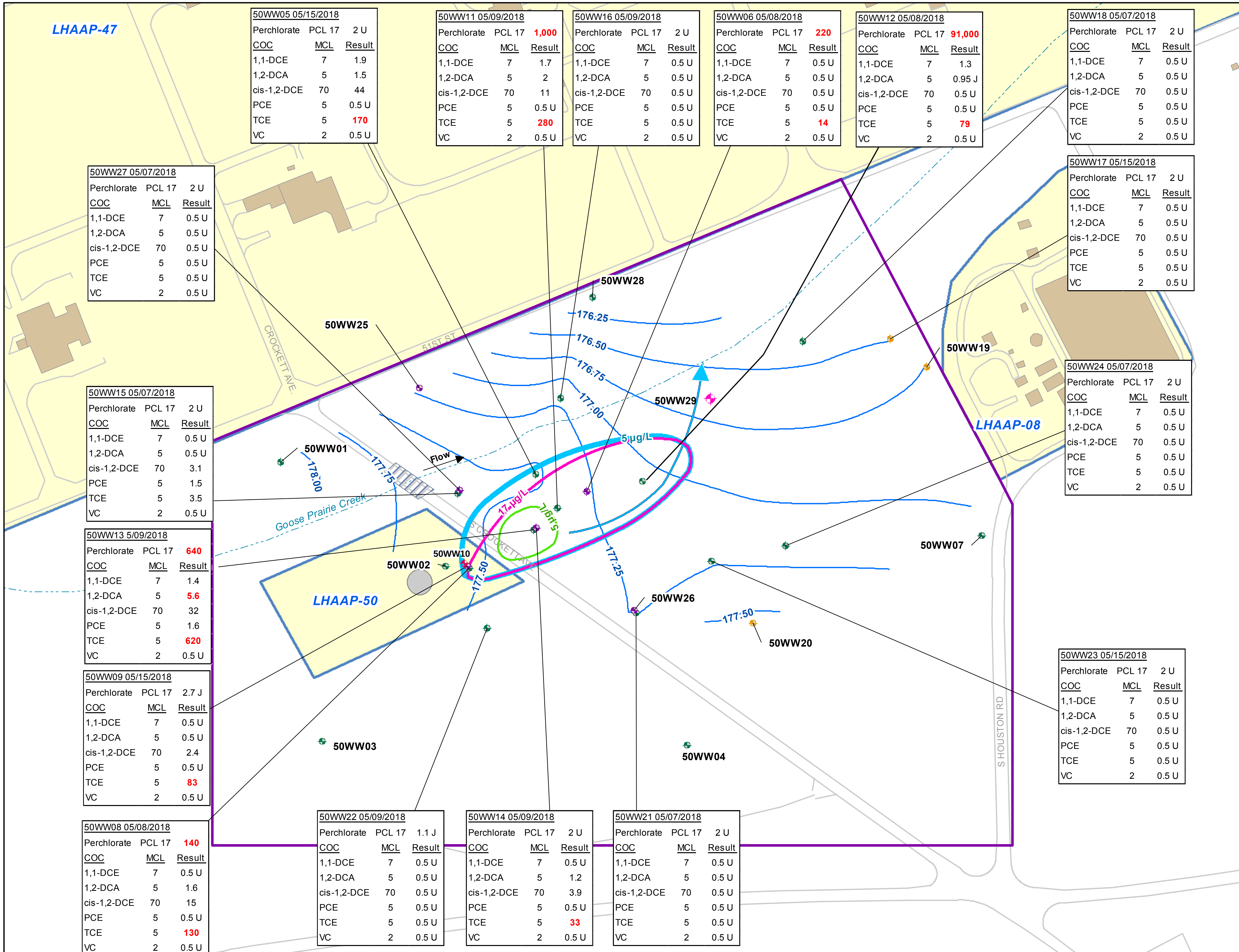
U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

bhate ENVIRONMENT & INFRASTRUCTURE
APTIM

Figure 1-5
COC Concentrations in Shallow Zone, May 2018

Remedial Action Work Plan, Contingency Remedy, LHAAP-50

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



50WW05 05/15/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	1.9
1,2-DCA	5	1.5
cis-1,2-DCE	70	44
PCE	5	0.5 U
TCE	5	170
VC	2	0.5 U

50WW11 05/09/2018

COC	MCL	Result
Perchlorate	PCL 17	1,000
1,1-DCE	7	1.7
1,2-DCA	5	2
cis-1,2-DCE	70	11
PCE	5	0.5 U
TCE	5	280
VC	2	0.5 U

50WW16 05/09/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW06 05/08/2018

COC	MCL	Result
Perchlorate	PCL 17	220
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	14
VC	2	0.5 U

50WW12 05/08/2018

COC	MCL	Result
Perchlorate	PCL 17	91,000
1,1-DCE	7	1.3
1,2-DCA	5	0.95 J
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	79
VC	2	0.5 U

50WW18 05/07/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW27 05/07/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW17 05/15/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW15 05/07/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	3.1
PCE	5	1.5
TCE	5	3.5
VC	2	0.5 U

50WW24 05/07/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW13 5/09/2018

COC	MCL	Result
Perchlorate	PCL 17	640
1,1-DCE	7	1.4
1,2-DCA	5	5.6
cis-1,2-DCE	70	32
PCE	5	1.6
TCE	5	620
VC	2	0.5 U

50WW09 05/15/2018

COC	MCL	Result
Perchlorate	PCL 17	2.7 J
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	2.4
PCE	5	0.5 U
TCE	5	83
VC	2	0.5 U

50WW23 05/15/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW08 05/08/2018

COC	MCL	Result
Perchlorate	PCL 17	140
1,1-DCE	7	0.5 U
1,2-DCA	5	1.6
cis-1,2-DCE	70	15
PCE	5	0.5 U
TCE	5	130
VC	2	0.5 U

50WW22 05/09/2018

COC	MCL	Result
Perchlorate	PCL 17	1.1 J
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW14 05/09/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	1.2
cis-1,2-DCE	70	3.9
PCE	5	0.5 U
TCE	5	33
VC	2	0.5 U

50WW21 05/07/2018

COC	MCL	Result
Perchlorate	PCL 17	2 U
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

New Installed Monitoring Well Location
Lower Shallow Monitoring Well
Upper Shallow Monitoring Well
Fully Penetrating Shallow Monitoring Well
Intermediate Monitoring Well
1,2-DCA Contour
Perchlorate Contour (*Dashed where inferred*)
TCE Contour
Groundwater Flow Direction
Groundwater Contour
Goose Prairie Creek
Roads
Land Use Control Boundary
Bridges
Former Storage Tank Location
Buildings
Site Boundaries

Notes:
1. All concentrations are shown in micrograms per liter (µg/L).
2. 1,1-DCE = 1,1-dichlorothene
   1,2-DCA = 1,2-dichlorethane
   cis-1,2-DCE = cis-1,2-dichloroethene
   PCE = tetrachloroethene
   TCE = trichloroethene
   VC = vinyl chloride
   MCL = maximum concentration level
   PCL = protective concentration level
   U = below detection limit
   J = estimated value
   COC = contaminant of concern
3. Results in red are above the MCL or PCL.
4. Groundwater Contours are based on May 2018 data.

0 75 150 Feet

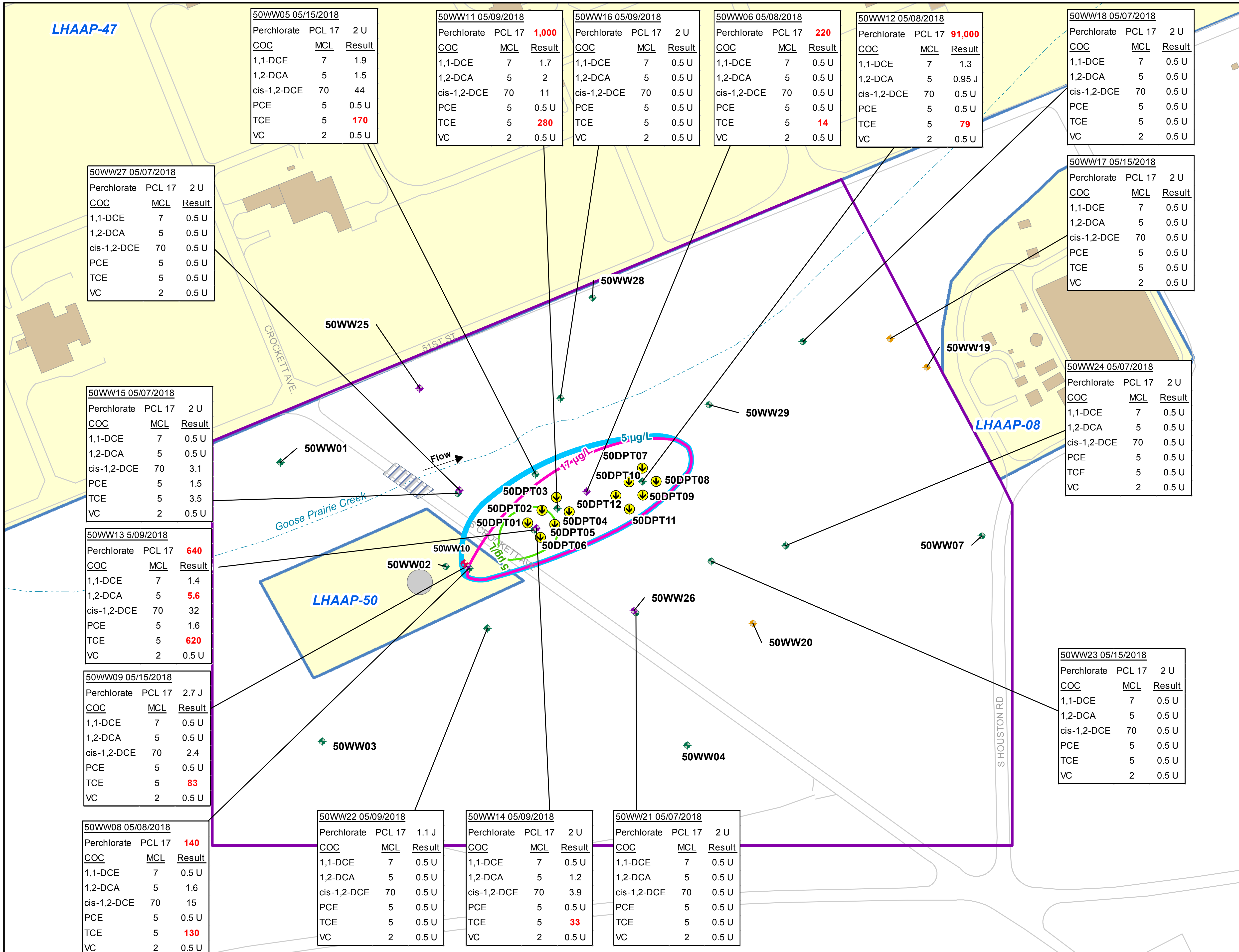
APTIM

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

Figure 2-1
New Well Location

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



50WW05 05/15/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	1.9
1,2-DCA	5	1.5
cis-1,2-DCE	70	44
PCE	5	0.5 U
TCE	5	170
VC	2	0.5 U

50WW11 05/09/2018

Perchlorate	PCL 17	1,000
COC	MCL	Result
1,1-DCE	7	1.7
1,2-DCA	5	2
cis-1,2-DCE	70	11
PCE	5	0.5 U
TCE	5	280
VC	2	0.5 U

50WW16 05/09/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW06 05/08/2018

Perchlorate	PCL 17	220
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	14
VC	2	0.5 U

50WW12 05/08/2018

Perchlorate	PCL 17	91,000
COC	MCL	Result
1,1-DCE	7	1.3
1,2-DCA	5	0.95 J
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	79
VC	2	0.5 U

50WW18 05/07/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW27 05/07/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW17 05/15/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW15 05/07/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	3.1
PCE	5	1.5
TCE	5	3.5
VC	2	0.5 U

50WW24 05/07/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW13 5/09/2018

Perchlorate	PCL 17	640
COC	MCL	Result
1,1-DCE	7	1.4
1,2-DCA	5	5.6
cis-1,2-DCE	70	32
PCE	5	1.6
TCE	5	620
VC	2	0.5 U

50WW09 05/15/2018

Perchlorate	PCL 17	2.7 J
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	2.4
PCE	5	0.5 U
TCE	5	83
VC	2	0.5 U

50WW23 05/15/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW08 05/08/2018

Perchlorate	PCL 17	140
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	1.6
cis-1,2-DCE	70	15
PCE	5	0.5 U
TCE	5	130
VC	2	0.5 U

50WW22 05/09/2018

Perchlorate	PCL 17	1.1 J
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

50WW14 05/09/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	1.2
cis-1,2-DCE	70	3.9
PCE	5	0.5 U
TCE	5	33
VC	2	0.5 U

50WW21 05/07/2018

Perchlorate	PCL 17	2 U
COC	MCL	Result
1,1-DCE	7	0.5 U
1,2-DCA	5	0.5 U
cis-1,2-DCE	70	0.5 U
PCE	5	0.5 U
TCE	5	0.5 U
VC	2	0.5 U

Lower Shallow Monitoring Well
Upper Shallow Monitoring Well
Fully Penetrating Shallow Monitoring Well
Intermediate Monitoring Well
Proposed DPT Point
1,2-DCA Contour
Perchlorate Contour
(*Dashed where inferred*)
TCE Contour
Goose Prairie Creek
Roads
Land Use Control Boundary
Bridges
Former Storage Tank Location
Buildings
Site Boundaries

Notes:
1. All concentrations are shown in micrograms per liter (µg/L).
2. 1,1-DCE = 1,1-dichlorothene
1,2-DCA = 1,2-dichlorethane
cis-1,2-DCE = cis-1,2-dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene
VC = vinyl chloride
MCL = maximum concentration level
PCL = protective concentration level
U = below detection limit
J = estimated value
COC = contaminant of concern
3. Results in red are above the MCL or PCL.

0 75 150 Feet

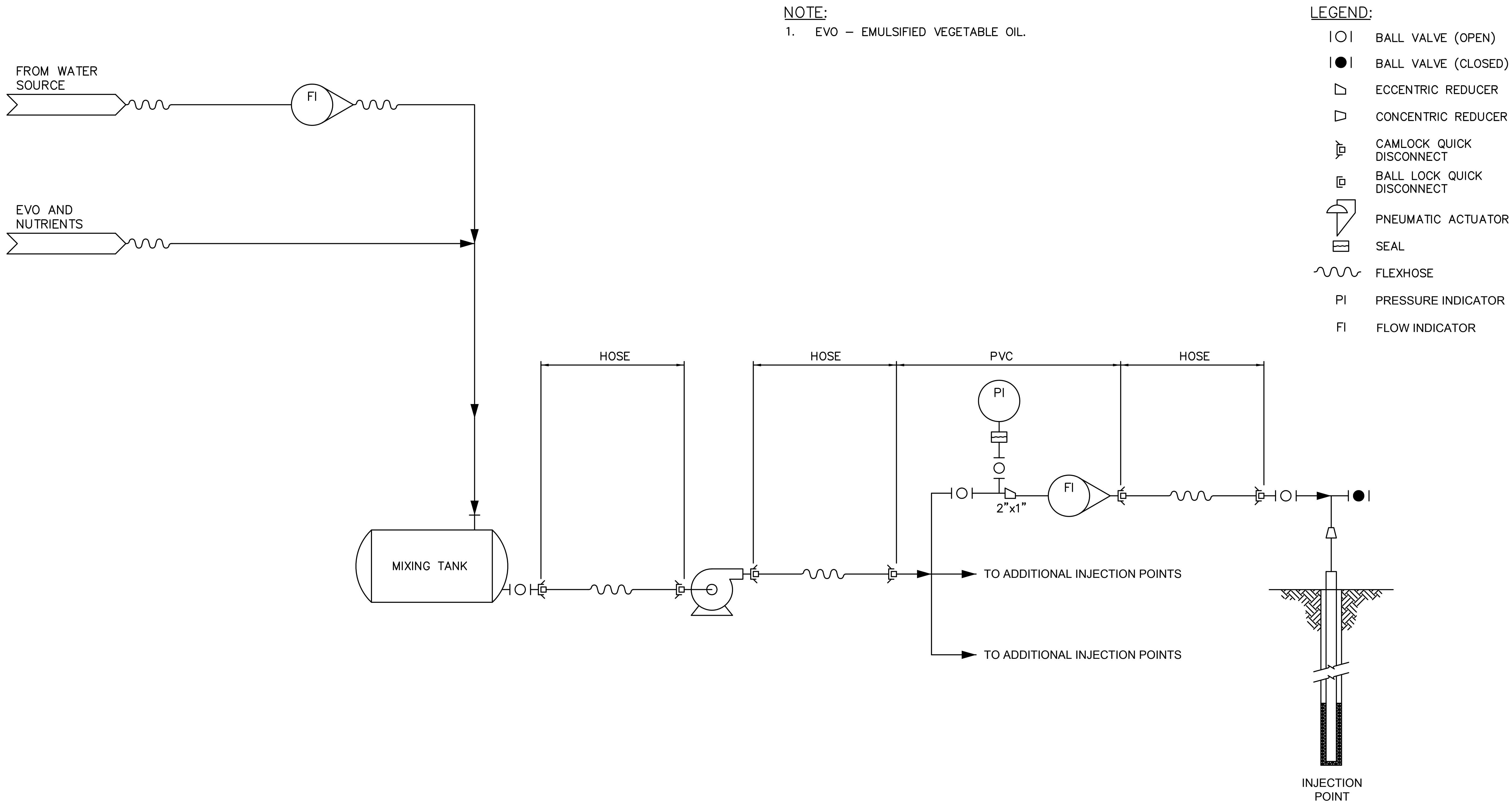
U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

bhate ENVIRONMENT & INFRASTRUCTURE
APTIM

Figure 3-1

Proposed Remediation Plan
Remedial Action Work Plan,
Contigency Remedy,
LHAAP-50
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP50_PropRemPlan.mxd Date: 10/31/2019



U.S. ARMY CORP OF ENGINEERS TULSA DISTRICT
TULSA, OKLAHOMA

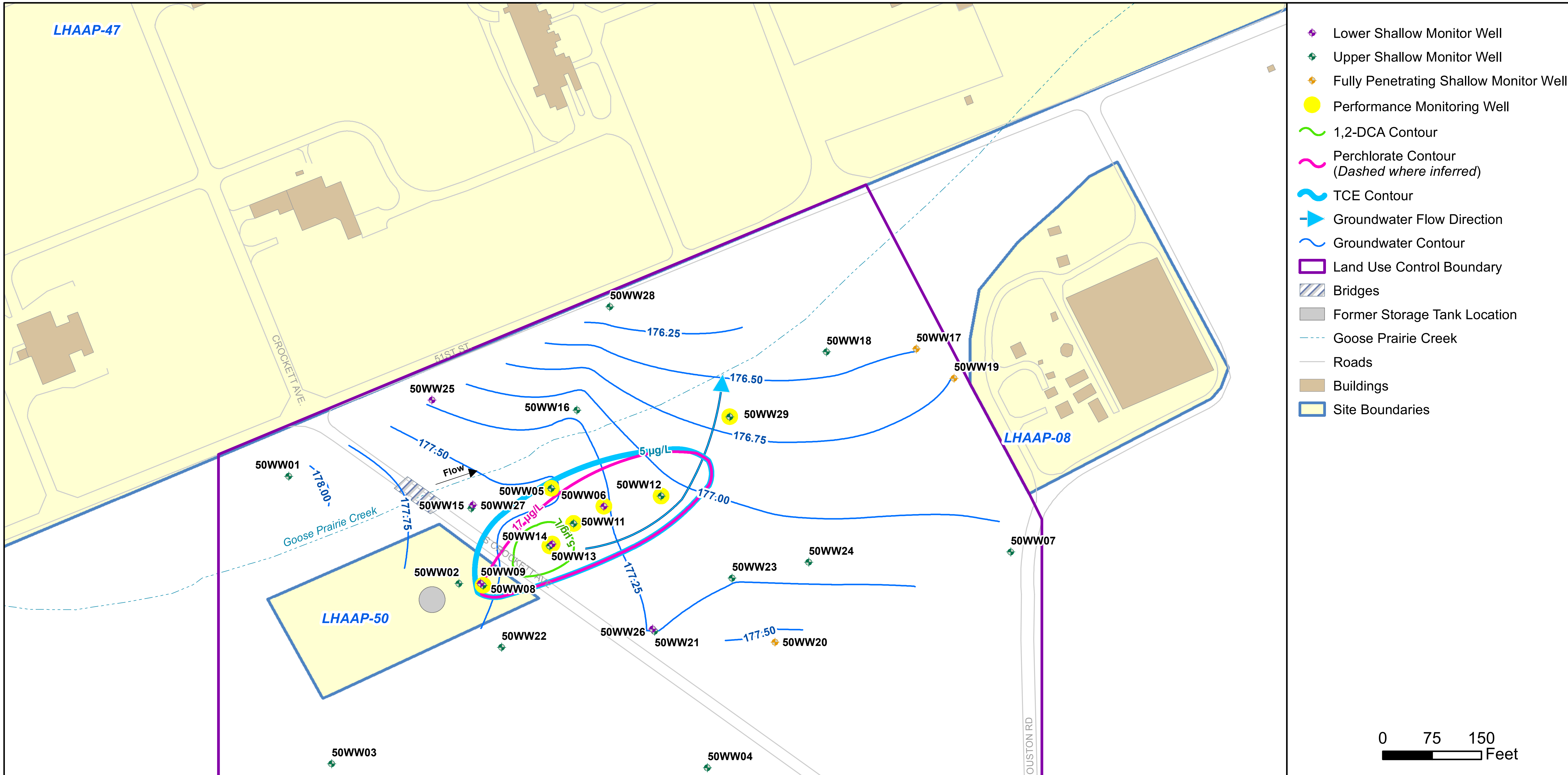
bhate ENVIRONMENT & INFRASTRUCTURE

APTIM

Figure 4-1
ISB DPT Injection System

Remedial Action Work Plan,
Contingency Remedy, LHAAP-50
Longhorn Army Ammunition Plant
Karnack, Texas

G:\Ft_Gillem\GIS_Documents\Output\FTG_07\FTG07_Treatment_System_Diagrams\FTG07_ISEB-DPT Injection System.ai



APTIM

U.S. ARMY CORP OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

Figure 5-1
Performance Monitoring Network
Remedial Action Work Plan,
Contigency Remedy,
LHAAP-50

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP50\RAWP\LHAAP50_PerformanceMonitoringNetwork.mxd Date: 10/31/2019

Appendix A

ISB Design Calculation Sheets

LHAAP-50: 50WW12 Treatment Area Calculation Worksheet

Site Parameters	units	LHAAP 50
Target Width	feet	59
Target Length	feet	59
Treatment Interval	feet	18
Target Area Volume	cubic feet	62,658
Effective Porosity		0.28
Target Area Water Volume	cubic feet	17,544
Target Area Water Volume	gallons	131,231
Target Injection Volume (10%)	gallons	13,123
Amendment Volume Requirements		
Emulsified Vegetable Oil: 60%	pounds	3,628
Emulsified Vegetable Oil: EDS-ER™ (100%)	pounds	2,177
Emulsified Vegetable Oil: EDS-ER™	gallons	283
Emulsified Vegetable Oil: EDS-ER™	drums	5
Dechlorinating culture:SDC-9™	liter	30
Dechlorinating culture:SDC-9™	gallon	8
Nutrients (DAP)	pounds	793
Water	gallons	12,832
Sodium Bicarbonate Buffer (0.87 g/L)	pounds	95
Volumes per Point		
Emulsified Vegetable Oil: EDS-ER™	gallons	48
SDC-9™	gallons	1.32
SDC-9™	liters	5.00
Nutrients (DAP)	pounds	132
Water	gallons	2,139
Sodium Bicarbonate Buffer	pounds	16
Injection Parameters		
Injection Spacing	feet	20
Target Depth	ft bgs	35
Thickness	feet	18
Total Volume per Point	gallons	2,188
Volume per foot		122
Injection Rate	gpm	3
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	13
Simultaneous Points	points	4
Hours of Injection per day	hours	8
Gallons per day	gallons	5,760
Points to be Completed	points	6
Days of Injection	days	2

Notes:

ft bgs - feet below ground surface

psi - pounds per square inch

gpm - gallons per minute

Nutrient Dosing Calculation Sheet

APTIM

Site Name: Longhorn AAP
Location: LHAAP-50 50WW12
Project No.:

Carbon content of soybean oil

Major component is linoleic acid				
CH3(CH2)4CH=CHCH2CH=CH(CH2)7 CO2CH3, or C19H34O2				
Formula weight:	294.48	grams per mole		
Carbon content:	77.42%			

Carbon content of 100% soybean oil EVO

Density of EVO	7.70	pounds/gallon		
Mass of EVO	2,177	pounds		
Mass of EVO	987	kilograms		
Volume of EVO	283	gallons		
55 gal drum of EVO	5.14	gallons		
Grade of EVO	100%			
Mass of carbon	764.56	kilograms		
Mass of carbon	1,682.03	pounds		

Nutrient demand based on 100C:10N:1P ratio

Carbon	1,682	pounds		
Nitrogen	168	pounds		
Phosphate	17	pounds		

Nutrient source required

DAP	**793**	lbs		

N & P content of nutrient sources

Diammonium Phosphate (DAP) solid (16-46-10)

	molecular wt.	atoms	total wt.	%
Nitrogen	14.0067	2	28.0134	21.21328922
Hydrogen	1.0079	9	9.0711	6.869136479
Phosphate	30.9738	1	30.9738	23.45506713
Oxygen	15.9994	4	63.9976	48.46250717
		Total	**132.1**	**100**
		100 lbs of DAP =21.2 lbs of N		
		4.71	lbs DAP for 1 lb N	

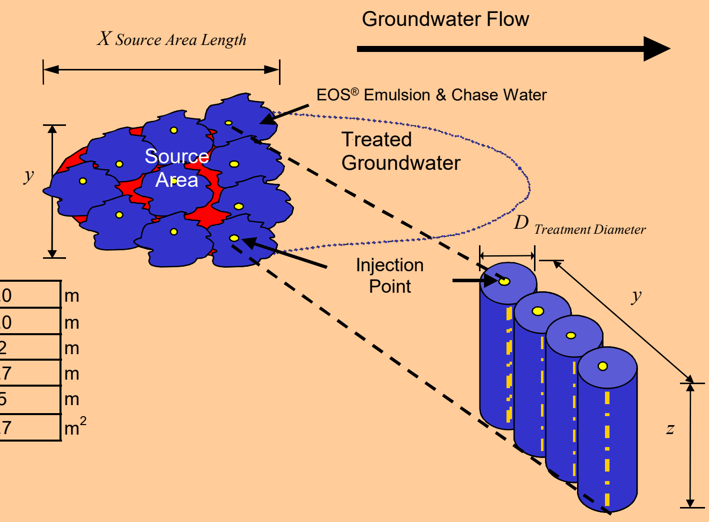
EOS® SOURCE AREA & DNAPL DESIGN WORKSHEET

U.S. Version 2.1f, Rev. Date: June 18, 2008
www.EOSRemediation.com

EOS Remediation, LLC

Help

Site Name:	Longhorn AAP	LHAAP 50
Location:	Karnack, TX	50WW12
Project No.:	501307071	



Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list) — EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here

Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Source Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	59	ft	18.0	m
Width of treatment area perpendicular to groundwater flow, "y"	59	ft	18.0	m
Minimum depth to contamination	17	ft	5.2	m
Maximum depth of contamination	35	ft	10.7	m
Treatment thickness, "z"	18	ft	5.5	m
Treatment zone cross-sectional area, A = y * z	1,062	ft^2	98.7	m^2

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Sand			
Total Porosity (accept default or enter *n*)	0.30	(decimal)		
Effective Porosity (accept default or enter n_e)	0.28	(decimal)		
Soil bulk density; (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.86	g/cc	116	lbs / ft^3
Fraction of organic carbon: foc	0.0050	range: 0.0001 to 0.01		

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter *K*)	0.4	ft/day	1.4E-04	cm/sec
Hydraulic Gradient (accept default or enter *i*)	0.004	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter $-i$ in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	LESS THAN	0.01	ft/day	LESS THAN	0.003	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$		12.71	gallons/day	LESS THAN	84.20	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)		60	typical values 60 to 180 days, see comment		
Calculated Contact Length $(x) = \tau * V_x$	Suggested Minimum	5.0	ft	1.5	m

Treatment zone volume	62,658	ft^3	1,774	m^3
Treatment zone groundwater volume (volume * porosity)	140,605	gallons	532,283	L

Section D: Design Lifespan For One Application

Section D: Design Lifespan For One Application	5	year(s)	typical values 5 to 10 years	
Estimated total groundwater volume treated over design life	163,800	gallons	685,954	L

Section E: Electron Acceptors

Dissolved Phase Electron Donor Demand

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e^- equiv./ mole	Stoichiometry Contaminant/H_2 (wt/wt H_2)	Hydrogen Demand (g H_2)
Dissolved Oxygen (DO)	0 to 8	0.69	32.0	4	7.94	59.63311906
Nitrate Nitrogen (NO_3^- - N)	1 to 10	0.483	62.0	5	12.30	26.92794793
Sulfate (SO_4^{2-})	10 to 500	432	96.1	8	11.91	24874.48727
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		0.079	131.4	6	21.73	2.494203017
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		0.0005	96.9	4	24.05	0.014263368
Vinyl Chloride (VC), C_2H_3Cl			62.5	2	31.00	
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
Chloroethane, C_2H_5Cl			64.9	2	32.18	
Perchlorate, ClO_4^-		91	99.4	8	12.33	5062.096768
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	
User added						
User added						
User added						

Sorbed Phase Electron Donor Demand

The concentration of the sorbed contaminant can be estimated by: $C_{SOIL} = K_{OC} \times f_{oc} \times C_{WATER}$

Where: K_{oc} is partition coefficient with respect to organic carbon.
f_{oc} (fraction organic carbon) is the mass of organic matter in soil divided by the total mass of soil
C_{WATER} is the concentration of the contaminant in the groundwater

Default values for Koc taken from: US EPA, Superfund Section, APPENDIX K, Soil Organic Carbon (Koc) / Water (Kow) Partition Coefficients (Average Value Used)

Inputs Adjust *Koc* as necessary to provide site specific estimates or enter sediment concentration (C_{SOIL})	K_{oc} (L/kg)	C_{SOIL} (mg/Kg)	Mass (g)	Hydrogen Demand (g H_2)
Tetrachloroethene (PCE), C_2Cl_4	272			
Trichloroethene (TCE), C_2HCl_3	97	0.04	126.11	5.80
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$	38	0.00	0.31	0.01
Vinyl Chloride (VC), C_2H_3Cl	241			
Carbon tetrachloride, CCl_4	158			
Chloroform, $CHCl_3$	53			
sym-tetrachloroethane, $C_2H_2Cl_4$	79			
1,1,1-Trichloroethane (TCA), CH_3CCl_3	139			
1,1-Dichloroethane (DCA), CH_2CHCl_2	54			
User added				
User added				
User added				

Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e^- equiv./ mole	Stoichiometry *Contaminant / H_2*	Hydrogen Demand *(g H_2)*	DOC Released *(moles)*
Estimated Amount of $Fe2^{+}$ Formed	10 to 100	50	55.8	1	55.41	619.0102555	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	125.8459635	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	3447.683315	
Target Amount of DOC to Release	60 to 100	100	12.0				5711.04

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,
2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	150.8	pounds
DOC Released	652.1	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

1,339 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%) 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated 1,814,010 lbs

Adsorptive Capacity of Soil (accept default or enter site specific value) 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

3,628 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project 9 drums

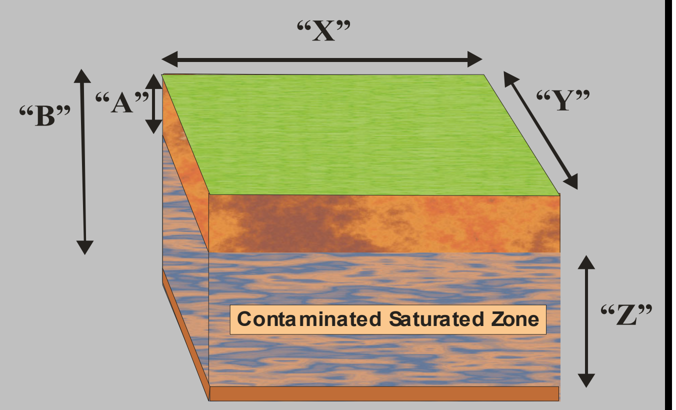
SDC-9 Dosage Estimating Software

APTIM

Site Name:	Longhorn AAP 50
Location:	LHAAP 50 50WW12
Project No.:	

Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "X"	59	ft	18.0	m
Width of treatment area perpendicular to groundwater flow, "Y"	59	ft	18.0	m
Minimum depth to contamination, "A"	17	ft	5.2	m
Maximum depth of contamination, "B"	35	ft	10.7	m
Treatment thickness, "Z"	18	ft	5.5	m



Site Data

Soil Characteristics

Nominal Soil Type (enter clay, silt, silty sand, or sand)	sand			
Hydraulic Characteristics				
Effective Porosity (accept default or enter n_e)	0.28	(decimal)		
Treatment zone volume	62,658			
Treatment zone water volume	17,544	ft^3	496,798	L

Dechlorinating Consortium Concentration

Dehalococcoides like organisms/L as determined by qPCR > **1.0E+11**

Design Final Concentration (DHC/L) (accept default or enter concentration) 6.00E+06 typical values 5 x 10^6 to 1 x 10^7

Suggested Quantity of Dechlorinating Consortium 30 Liters

LHAAP-50: 50WW14 Treatment Area Calculation Worksheet

Site Parameters	units	LHAAP 50
Target Width	feet	59
Target Length	feet	59
Treatment Interval	feet	42
Target Area Volume	cubic feet	146,202
Effective Porosity		0.28
Target Area Water Volume	cubic feet	40,937
Target Area Water Volume	gallons	306,205
Target Injection Volume (10%)	gallons	30,621
Amendment Volume Requirements		
Emulsified Vegetable Oil: EOS (60%)	pounds	8,465
Emulsified Vegetable Oil: EDS-ER™ (100%)	pounds	5,079
Emulsified Vegetable Oil: EDS-ER™	gallons	660
Emulsified Vegetable Oil: EDS-ER™	drums	12
Dechlorinating Culture SDC-9™	liter	70
Dechlorinating Culture SDC-9™	gallon	18
Nutrients (DAP)	pounds	1,850
Water	gallons	29,942
Sodium Bicarbonate Buffer (0.87g/L)	pounds	222
Volumes per Point		
Emulsified Vegetable Oil (EDS-ER™)	gallons	110
SDC-9™	gallons	3.08
SDC-9™	liters	12
Nutrients (DAP)	pounds	308
Water	gallons	4,990
Sodium Bicarbonate Buffer	Pounds	37
Injection Parameters		
Injection Spacing	feet	20
Target Depth	ft bgs	60
Thickness	feet	42
Total Volume per Point	gallons	5,103
Volume per foot		122
Injection Rate	gpm	3
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	29
Simultaneous Points	points	4
Hours of Injection per day	hours	8
Gallons per day	gallons	5,760
Points to be Completed	points	6
Days of Injection	days	5

Notes:

Table will be updated with buffer amount based on buffer capacity test results.

ft bgs - feet below ground surface

psi - pounds per square inch

gpm - gallons per minute

Nutrient Dosing Calculation Sheet

APTIM

Site Name: Longhorn AAP
Location: LHAAP-50 50WW14
Project No.:

Carbon content of soybean oil

Major component is linoleic acid				
CH3(CH2)4CH=CHCH2CH=CH(CH2)7 CO2CH3, or C19H34O2				
Formula weight:	294.48	grams per mole		
Carbon content:	77.42%			

Carbon content of 100% soybean oil EVO

Density of EVO	7.70	pounds/gallon		
Mass of EVO	5,079	pounds		
Mass of EVO	2,304	kilograms		
Volume of EVO	660	gallons		
55 gal drum of EVO	11.99	gallons		
Grade of EVO	100%			
Mass of carbon	1,783.73	kilograms		
Mass of carbon	3,924.22	pounds		

Nutrient demand based on 100C:10N:1P ratio

Carbon	3,924	pounds
Nitrogen	392	pounds
Phosphate	39	pounds

Nutrient source required

DAP	**1,850**	lbs

N & P content of nutrient sources

Diammonium Phosphate (DAP) solid (16-46-10)

	molecular wt.	atoms	total wt.	%
Nitrogen	14.0067	2	28.0134	21.21328922
Hydrogen	1.0079	9	9.0711	6.869136479
Phosphate	30.9738	1	30.9738	23.45506713
Oxygen	15.9994	4	63.9976	48.46250717
		Total	**132.1**	**100**
		100 lbs of DAP =21.2 lbs of N		
		4.71	lbs DAP for 1 lb N	

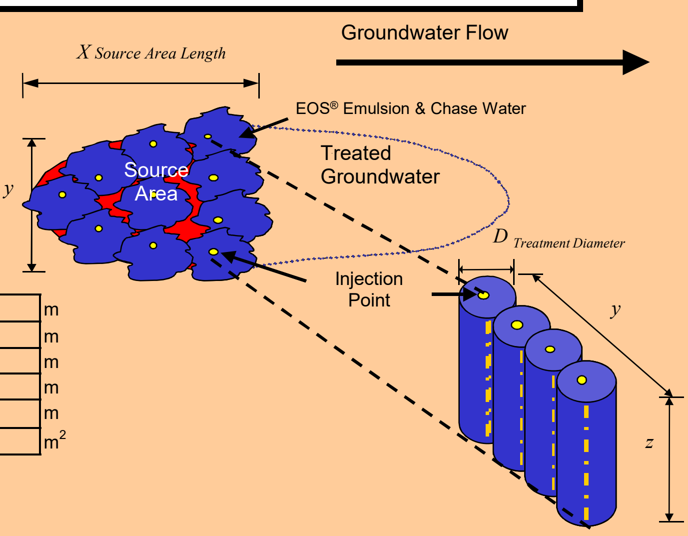
EOS® SOURCE AREA & DNAPL DESIGN WORKSHEET

U.S. Version 2.1f, Rev. Date: June 18, 2008
www.EOSRemediation.com

EOS Remediation, LLC

Help

Site Name:	Longhorn AAP	LHAAP 50
Location:	Karnack, TX	50WW14, 50WW11
Project No.:	501307071	



Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list) — EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here

Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Source Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	59	ft	18.0	m
Width of treatment area perpendicular to groundwater flow, "y"	59	ft	18.0	m
Minimum depth to contamination	18	ft	5.5	m
Maximum depth of contamination	60	ft	18.3	m
Treatment thickness, "z"	42	ft	12.8	m
Treatment zone cross-sectional area, A = y * z	2,478	ft^2	230.2	m^2

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter *n*)	0.30	(decimal)		
Effective Porosity (accept default or enter n_e)	0.28	(decimal)		
Soil bulk density; (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.86	g/cc	116	lbs / ft^3
Fraction of organic carbon: foc	0.0050	range: 0.0001 to 0.01		

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter *K*)	0.4	ft/day	1.4E-04	cm/sec
Hydraulic Gradient (accept default or enter *i*)	0.004	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter $-i$ in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	LESS THAN	0.01	ft/day	LESS THAN	0.003	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$		29.66	gallons/day	LESS THAN	196.47	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)		60	typical values 60 to 180 days, see comment		
Calculated Contact Length $(x) = \tau * V_x$	Suggested Minimum	5.0	ft	1.5	m
Treatment zone volume	146,202		ft^3	4,140	m^3
Treatment zone groundwater volume (volume * porosity)	328,077		gallons	1,241,994	L

Section D: Design Lifespan For One Application

Section D: Design Lifespan For One Application	5	year(s)	typical values 5 to 10 years	
Estimated total groundwater volume treated over design life	382,201	gallons	1,600,558	L

Section E: Electron Acceptors

Dissolved Phase Electron Donor Demand

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e^- equiv./ mole	Stoichiometry Contaminant/H_2 (wt/wt H_2)	Hydrogen Demand (g H_2)
Dissolved Oxygen (DO)	0 to 8	0.69	32.0	4	7.94	139.1439445
Nitrate Nitrogen (NO_3^- - N)	1 to 10	0.434	62.0	5	12.30	56.45762997
Sulfate (SO_4^{2-})	10 to 500	432	96.1	8	11.91	58040.47029
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		0.28	131.4	6	21.73	20.62716419
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		0.011	96.9	4	24.05	0.732186231
Vinyl Chloride (VC), C_2H_3Cl			62.5	2	31.00	
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
Chloroethane, C_2H_5Cl			64.9	2	32.18	
Perchlorate, ClO_4^-		1	99.4	8	12.33	129.797353
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	
User added						
User added						
User added						

Sorbed Phase Electron Donor Demand

The concentration of the sorbed contaminant can be estimated by: $C_{SOIL} = K_{OC} \times f_{oc} \times C_{WATER}$

Where: K_{oc} is partition coefficient with respect to organic carbon.
f_{oc} (fraction organic carbon) is the mass of organic matter in soil divided by the total mass of soil
C_{WATER} is the concentration of the contaminant in the groundwater

Default values for Koc taken from: US EPA, Superfund Section, APPENDIX K, Soil Organic Carbon (Koc) / Water (Kow) Partition Coefficients (Average Value Used)

Inputs Adjust *Koc* as necessary to provide site specific estimates or enter sediment concentration (C_{SOIL})	K_{oc} (L/kg)	C_{SOIL} (mg/Kg)	Mass (g)	Hydrogen Demand (g H_2)
Tetrachloroethene (PCE), C_2Cl_4	272			
Trichloroethene (TCE), C_2HCl_3	97	0.14	1042.90	48.00
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$	38	0.00	16.05	0.67
Vinyl Chloride (VC), C_2H_3Cl	241			
Carbon tetrachloride, CCl_4	158			
Chloroform, $CHCl_3$	53			
sym-tetrachloroethane, $C_2H_2Cl_4$	79			
1,1,1-Trichloroethane (TCA), CH_3CCl_3	139			
1,1-Dichloroethane (DCA), CH_2CHCl_2	54			
User added				
User added				
User added				

Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e^- equiv./ mole	Stoichiometry *Contaminant / H_2*	Hydrogen Demand *(g H_2)*	DOC Released *(moles)*
Estimated Amount of $Fe2^+$ Formed	10 to 100	50	55.8	1	55.41	1444.357263	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	293.6405815	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	8044.594402	
Target Amount of DOC to Release	60 to 100	100	12.0				13325.77

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,
2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	300.5	pounds
DOC Released	1,521.6	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

2,891 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%) 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated 4,232,689 lbs

Adsorptive Capacity of Soil (accept default or enter site specific value) 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

8,465 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project 21 drums

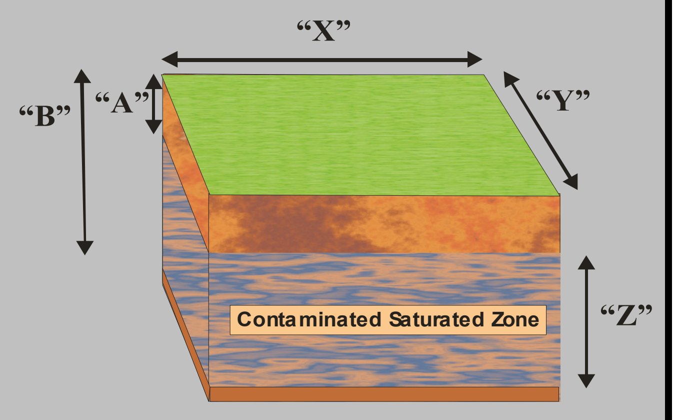
†Exclusive license agreement with Solutions-IES under U.S. Patent # 6,398,960, E.U. Patent # EP 1 315 675 and several other pending international patents.
††EOS® is a registered trademark of EOS Remediation, LLC

SDC-9 Dosage Estimating Software

Site Name:	Longhorn AAP 50
Location:	LHAAP 50
Project No.:	

Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	59	ft	18.0	m
Width of treatment area perpendicular to groundwater flow, "y"	59	ft	18.0	m
Minimum depth to contamination, "A"	18	ft	5.5	m
Maximum depth of contamination, "B"	60	ft	18.3	m
Treatment thickness, "z"	42	ft	12.8	m



Site Data

Soil Characteristics

Nominal Soil Type (enter clay, silt, silty sand, or sand)	silt			
Hydraulic Characteristics				
Effective Porosity (accept default or enter n_e)	0.28	(decimal)		
Treatment zone volume	146,202			
Treatment zone water volume	40,937	ft^3	1,159,194	L

Dechlorinating Consortium Concentration

Dehalococcoides like organisms/L as determined by qPCR > **1.0E+11**

Design Final Concentration (DHC/L) (accept default or enter concentration) 6.00E+06 typical values 5 x 10^6 to 1 x 10^7

Suggested Quantity of Dechlorinating Consortium 70 Liters

Appendix B

Product Specification and Safety Data Sheets

Tech Brief

Enhanced Anaerobic Bioremediation

Tersus Environmental
For every zone of your plume, we've got you covered!

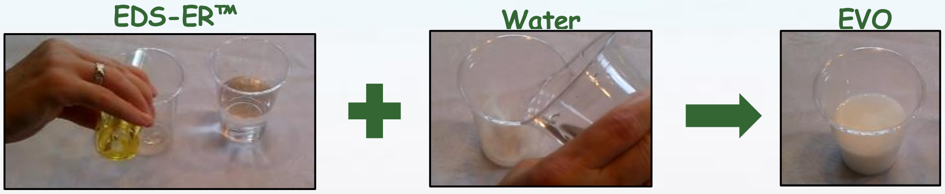
EDS-ER™

Electron Donor Solution – Extended Release

As delivered, the physical state of *EDS-ER™* (electron donor solution – extended release) by Tersus Environmental is significantly different than standard emulsified vegetable oil (EVO) products. Whereas other EVO products are concentrated emulsions containing water, *EDS-ER™* is a water-mixable oil; it contains no water. Thus, the costs for shipping EDS-ER are about 50% less than conventional products.

At room temperature, *EDS-ER™* is a liquid material with an appearance and viscosity roughly equivalent to vegetable oil. Unlike common EVO products, *EDS-ER™* will not separate, will not freeze, and has a shelf life of 2 years without spoilage.

Tersus Environmental is proud to announce that *EDS-ER™* does NOT contain ethoxylated surfactants. As you may know, many environmental remediation injectates, such as emulsified vegetable oils use biodegradable non-ionic surfactants. Unfortunately, ethoxylation, the manufacturing process that creates these surfactants (e.g., polysorbates) often results in these products containing 1,4-dioxane.



Purpose

EDS-ER™ is a simple, safe, low-cost solution for the bioremediation of halogenated compounds (e.g., PCE, TCE, DCE, VC, TCA, CT, etc.), perchlorate, explosives such as aromatic nitrates, energetic munitions residuals, nitrates, acids, radionuclides, select oxidized heavy metals, and other contaminants.

Benefits

- 100% fermentable and contains no water
- Because the product is completely water mixable, the number of necessary injection points for low permeability structures decreases
- Easily mixes with water, simplifying field operations
- Controlled release of electron donors for up to five years
- Food-grade carbon source
- Low total dissolved solids to comply with secondary water quality requirements for amendments with low salt content
- Conforms to EPA's EPP (Environmentally Preferable Purchasing) and USDA biobased criteria
- Neutral pH when mixed with water
- Clean, low-cost, non-disruptive application (e.g., direct-push, wells and excavations)
- Lowers transportation costs when compared to other electron donors
- Over two years shelf life
- Freezing Point is -4 °F (-20 °C)

Field Application Design

EDS-ER™ applications are easily tailored to meet site-specific conditions. Typical configurations consist of grid and barrier patterns and application in excavations or trenches. The product's low viscosity allows subsurface distribution through direct-push injection points, hollow-stem augers or pumped through existing wells.

Packaging Options

- 55-gallon poly drums
- 275-gallon IBC containers
- 3,000 - 5,000 gallon tankers

tersus environmental

tersusenv.com • tersusenv.fr • tersusenv.es
919.453.5577 • info@tersusenv.com

Electron Donor Solution

Section 1: Chemical Product and Company Identification

Product Name: Electron Donor Solution Extended Release
Catalog Codes: EDS-ER
CAS#: 8001-22-7
TSCA: TSCA 8(b) inventory: Soybean oil
HMIS Code: H F R P: 10 0 A
Trade Name and Synonyms: EDS-ER
Chemical Family: Glyceride Oils

Contact Information:
Tersus Environmental, LLC
109 E. 17th Street, Suite #3880
Cheyenne, WY 82001
Ph: 307.638.2822 • info@tersusenv.com
www.tersusenv.com
For emergency assistance, call: 919.638.7892

Section 2: Composition and Information on Ingredients

COMPONANT	CAS #	OSHA TWA	OSHA STEL	ACGIH TWA	ACGIH STEL
Soybean Oil	8001-22-7	---	10 mg/m^3	---	---
Vegetable Oil Derived Fatty Acid Esters	Confidential	---	---	---	---

HAZARDOUS INGREDIENTS: NONE AS DEFINED UNDER THE U.S. OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200) OR THE CANADIAN HAZARDOUS PRODUCTS. ACT S.C. 1987, C.30 (PART 1).

THE PRECISE COMPOSITION OF THIS PRODUCT IS PROPRIETARY INFORMATION. A MORE COMPLETE DISCLOSURE WILL BE PROVIDED TO A PHYSICIAN IN THE EVENT OF A MEDICAL EMERGENCY.

SARA HAZARD: NONE NOTED (SECTION 311/312) TITLE III SECTION 313 - NOT LISTED
All components of this product are listed on the TSCA registry.

Section 3: Physical/Chemical Characteristics

BOILING RANGE: Not applicable VAPOR DENSITY: Exceeds 1.0

SPECIFIC GRAVITY (H20=1.0): 0.92 - 0.925 VAPOR PRESSURE: Not applicable

PERCENT VOLATILE BY VOLUME: 0% SOLUBILITY IN WATER: Miscible

EVAPORATION RATE: Not applicable
APPEARANCE AND ODOR: A pale yellow, oily liquid - only a faint odor.
WEIGHT PER GALLON: 7.7 lbs. at 60F.

Section 4: Fire and Explosion Data

FLAMMABILITY CLASSIFICATION: Combustible Liquid - Class IIIB.
FLASHPOINT: Greater than 550 F (288 C).
METHOD USED: Tag Closed Cup.
EXTINGUISHING MEDIA: CO_2, dry chemical, foam, sand.
SPECIAL FIREFIGHTING PROCEDURES: Avoid use of water as it may spread fire by dispersing oil. Use water to keep fire-exposed containers cool. Water spray may be used to flush spills away from fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Rags soaked with any oil or solvent can present a fire hazard and should always be stored in UL Listed or Factory Mutual approved, covered containers. Improperly stored rags can create conditions that lead to oxidation. Oxidation, under certain conditions can lead to spontaneous combustion.

Section 5: Reactivity Data

STABILITY: Generally stable. Spontaneous combustion can occur. See Unusual Fire and Explosion Procedures, Section IV.

CONDITIONS TO AVOID: High surface area exposure to oxygen can result in polymerization and release of heat.

INCOMPATABILITY (MATERIALS TO AVOID): Avoid contact with strong oxidizing agents.

HAZARDOUS DECOMPOSITIONS OR BY-PRODUCTS: Decomposition may produce carbon dioxide and carbon monoxide.

HAZARDOUS POLYMERIZATION: Will not occur.

Section 6: Health Hazard Data

THRESHHOLD LIMIT VALUE: As a liquid - none. As oil mist - 10 mg/m^3 total particulate.

INHALATION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: Excessive inhalation of oil mist may affect the respiratory system. Oil mist is classified as a nuisance particulate by ACGIH.

SKIN ABSORPTION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: Not classified as a primary skin irritant or corrosive material. Sensitive individuals may experience dermatitis after long exposure of oil on skin.

HEALTH HAZARDS (ACUTE AND CHRONIC): Acute: none observed by inhalation. Chronic: none reported.

EMERGENCY AND FIRST AID PROCEDURES FOR:

SKIN CONTACT: May be removed from skin by washing with soap and warm water.

EYE CONTACT: Immediately flush eyes with plenty of cool water for at least 15 minutes. Do NOT let victim rub eyes.

INHALATION: Immediately remove exposed individual to fresh air source. If victim has stopped breathing give artificial respiration, get medical attention immediately.

Section 7: Precautions for Safe Handling and Use

ENVIRONMENTAL PRECAUTIONS: Where large spills are possible, a comprehensive spill response plan should be developed and implemented.

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wear appropriate respiratory protection and protective clothing as described in section VIII. Depending on quantity of spill: (a) Small spill - add solid adsorbent, shovel into disposable container and wash the area. Clean area with detergent. (b) Large spill - Squeegee or pump into holding container. Clean area with detergent. In the event of an uncontrolled release of this material, the user should determine if this release is reportable under applicable laws and regulations.

WASTE DISPOSAL METHOD: All recovered material should be packaged, labeled, transported, and disposed or reclaimed in accordance with local, state, and federal regulations and good engineering practices.

Section 8: Control Measures

RESPIRATORY PROTECTION: Not normally needed. A qualified health specialist should evaluate whether there is a need for respiratory protection under specific conditions.

VENTILATION: Handle in the presence of adequate ventilation. Intermittent clean air exchanges recommended, but not required.

PROTECTIVE GLOVES: Not normally needed. However, protective clothing is always recommended when handling chemicals.

EYE PROTECTION: Eye protection is always recommended when handling chemicals. Wear safety glasses meeting the specifications established in ANSI Standard Z87.1.

Section 9: Special Precautions

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Store away from flame, fire, and excessive heat.

Section 10: Disposal Considerations

General Information: Do not discharge into drains, watercourses or onto the ground. Discharge, treatment, or disposal may be subject to national, state, or local laws. Empty containers may contain product residues.

Disposal Methods: No specific disposal method required.

Container: Since emptied containers retain product residue, follow label warnings even after container is emptied.

Section 11: Transportation Information

DOT Not regulated.
TDG Not regulated.
IATA Not regulated.
IMDG Not regulated.

Section 12: Other Information

Hazard Ratings

	Health Hazard	Fire Hazard	Instability	Special Hazard
NFPA	1	1	0	NONE

Hazard rating: 0 - Minimal; 1 - Slight; 2 - Moderate; 3 - Serious; 4 - Severe
NFPA Label colored diamond code: Blue - Health; Red - Flammability; Yellow - Instability; White - Special Hazards

	Health Hazard	Flammability	Physical Hazard	Personal Protection
HMIS	1	1	0	--

Hazard rating: 0 - Minimal; 1 - Slight; 2 - Moderate; 3 - Serious; 4 - Severe
HMIS Label colored bar code: Blue - Health; Red - Flammability; Orange - Physical Hazards; White - Special

Section 13: Disclaimer and/or Comments

We suggest that containers be either professionally reconditioned for re-use by certified firms or properly disposed of by certified firms to help reduce the possibility of an accident. Disposal of containers should be in accordance with applicable federal, state and local laws and regulations. "Empty" drums should not be given to individuals.

The conditions of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Tersus Environmental be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Tersus Environmental has been advised of the possibility of such damages.

Material Safety Data Sheet

Shaw Environmental, Inc.

17 PRINCESS ROAD
LAWRENCEVILLE, N.J. 08648
(609) 895-5340

SECTION 1 - MATERIAL IDENTIFICATION AND INFORMATION

Material Name: DHC microbial consortium (SDC-9) MSDS #: ENV 1033

Date Prepared: 10/06/2003 CAS #: N/A (Not Applicable)

Prepared By: Simon Vainberg Formula #: N/A

Material Description: Non-hazardous, naturally occurring non-altered anaerobic microbes and enzymes in a water-based medium.

SECTION 2 - INGREDIENTS

Components	%	OSHA PEL	ACGIH TLV	OTHER LIMITS
Non-Hazardous Ingredients	100	N/A	N/A	N/A

SECTION 3 - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: 100°C (water)

Specific Gravity (H_2O = 1): 0.9 - 1.1

Vapor Pressure @ 25°C: 24 mm Hg (water)

Melting Point: 0°C (water)

Vapor Density: N/A

Evaporation Rate (H_2O = 1): 0.9 - 1.1

Solubility in Water: Soluble

Water Reactive: No

pH: 6.0 - 8.0

Appearance and Odor: Murky, yellow water. Musty odor.

SECTION 4 - FIRE AND EXPLOSION HAZARD DATA

Flash Point: N/A

Flammable Limits: N/A

Extinguishing Media: Foam, carbon dioxide, water

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

SECTION 5 - REACTIVITY DATA

Stability: Stable

Conditions to Avoid: None

Incompatibility (Materials to Avoid): Water-reactive materials

Hazardous Decomposition Byproducts: None

SECTION 6 - HEALTH HAZARD DATA

HEALTH EFFECTS

The effects of exposure to this material have not been determined. Safe handling of this material on a long-term basis will avoid any possible effect from repetitive acute exposures. Below are possible health effects based on information from similar materials. Individuals hyper allergic to enzymes or other related proteins should not handle.

Ingestion: Ingestion of large quantities may result in abdominal discomfort including nausea, vomiting, cramps, diarrhea, and fever.

Inhalation: Hypersensitive individuals may experience breathing difficulties after inhalation of aerosols.

Skin Absorption: N/A

Skin Contact: May cause skin irritation. Hypersensitive individuals may experience allergic reactions to enzymes.

Eye Contact: May cause eye irritation.

FIRST AID

Ingestion: Get medical attention if allergic symptoms develop (observe for 48 hours). Never give anything by mouth to an unconscious or convulsing person.

Inhalation: Get medical attention if allergic symptoms develop.

Skin Absorption: N/A

Skin Contact: Wash affected area with soap and water. Get medical attention if allergic symptoms develop.

Eye Contact: Flush eyes with plenty of water for at least 15 minutes using an eyewash fountain, if available. Get medical attention if irritation occurs.

NOTE TO PHYSICIANS: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this material may have occurred.

SECTION 7 - SPILL AND LEAK PROCEDURES

Reportable quantities (in lbs of EPA Hazardous Substances): N/A

Steps to be taken in case of spill or release: No emergency results from spillage. However, spills should be cleaned up promptly. All personnel involved in the cleanup must wear protective clothing and avoid skin contact. Absorb spilled material or vacuum into a container. After clean-up, disinfect all cleaning materials and storage containers that come in contact with the spilled liquid.

Waste Disposal Method: No special disposal methods are required. The material may be sewered, and is compatible with all known biological treatment methods. To reduce odors and permanently inactivate microorganisms, mix 100 parts (by volume) of DHC consortium with 1 part (by volume) of bleach. Dispose of in accordance with local, state and federal regulations.

SECTION 8 - HANDLING AND STORAGE

Hand Protection: Rubber gloves.

Eye Protection: Safety goggles with side splash shields.

Protective Clothing: Use adequate clothing to prevent skin contact.

Respiratory Protection: Surgical mask.

Ventilation: Provide adequate ventilation to remove odors.

Storage & Handling:
Material may be stored for up to 3 weeks at 2-4°C without aeration.

Other Precautions: An eyewash station in the work area is recommended.

Appendix C

Daily ISB Injection Log

APTIM

Drilling Company: ____________________

Area: ____________

Injection Oversight: ____________________

Oversight Company: Aptim Federal Services, LLC

Injection Operator: ____________________

Injection Point	Date	Pressure (psi)	Total Volume (gal)	Flow Rate (gpm)	Start	End	Comments
LHAAP-04							
Total Volume 0							