

LONGHORN ARMY AMMUNITION PLANT KARNACK, TEXAS

ADMINISTRATIVE RECORD

CHRONOLOGICAL INDEX

Volume 2 of 25

2007

Bate Stamp Numbers

00043191 – 00043907

Prepared for

**Department of the Army
Longhorn Army Ammunition Plant**

1976 – 2007

***LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS
ADMINISTRATIVE RECORD – CHRONOLOGICAL INDEX***

VOLUME 2 of 25

2007

- A. Title: Report - Final Modeling Report Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment LHAAP Revision I
Author(s): Shaw
Recipient: All Stakeholders
Date: February 13, 2007
Bate Stamp: 00043191 - 00043522

- B. Title: Minutes - Draft Final Minutes, Monthly Managers Meeting
Author(s): Shaw
Recipient: All Stakeholders
Date: February 13, 2007
Bate Stamp: 00043523 - 00043533

- C. Title: Letter - Caddo Lake National Wildlife Refuge - Future Plans
Author(s): Mark Williams, Refuge Manager Fish and Wildlife Service
Recipient: Rose Zeiler, Site Manager LHAAP
Date: February 15, 2007
Bate Stamp: 00043534 - 00043535

- D. Title: Minutes - Draft Final Minutes, Monthly Managers Meeting
Author(s): Shaw
Recipient: All Stakeholders
Date: March 6, 2007
Bate Stamp: 00043536 - 00043547

- E. Title: Minutes - Draft Final Minutes, Monthly Managers Meeting
Author(s): Shaw
Recipient: All Stakeholders
Date: April 4, 2007
Bate Stamp: 00043548 - 00043558

- F. Title: Report - Final Site Evaluation Report LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53) (Former Static Test Area)
Author(s): Shaw
Recipient: All Stakeholders
Date: April 9, 2007
Bate Stamp: 00043559 - 00043907

February 8, 2007

Mr. Cliff Murray
U.S. Army Corps of Engineers – Tulsa District
1645 South 101st - East Avenue
Tulsa, Oklahoma 74128-4629

RE: **Task Order No. 109**
Total Environmental Restoration Contract (TERC)
Contract No. DACA56-94-D-0020
Environmental Investigation and Remediation at
Longhorn Army Ammunition Plant, Karnack, Texas
***Final Modeling Report, Revision 1, Derivation of Soil and Groundwater
Concentrations Protective of Surface Water and Sediment, Longhorn Army
Ammunition Plant, Karnack, Texas***

Dear Mr. Murray:

Shaw Environmental, Inc. is pleased to submit the attached Final Modeling Report, Revision 1 along with two CDs that will replace the CDs previously sent. We are also sending copies of the document and CDs directly to individuals on the attached project document distribution list.

Please contact me if you have any questions or require additional information.

Sincerely,



Praveen Srivastav, Ph.D., P.G.
Project Manager

Longhorn Distribution List

Member	Agency	Address	Phone No. e-mail address	No. of Copies
Cliff Murray Tulsa District	U.S. Army Corp of Engineers	US Army Corp of Engineers 1645 South 101 st – East Avenue Tulsa, Oklahoma 74128-4529	Office: 918-669-7573 Cliff.Murray@SWT03.usace.army.mil	2
Dr. Rose Zeiler	BRAC; Longhorn Site Manager	P.O. Box 220 Ratcliff, AR 72951 727 South Brooklyn Rd Ratcliff, AR 72951	Office: 479-635-0110 rose.zeiler@us.army.mil	1
Jeff Armstrong	Army Environmental Center	Commander USAEC SFIM-AEC-ERA (Attn: Jeff Armstrong) Beal Road Bldg E-4880 APG, MD 21010-5401	Office: 410-436-1516 jeffrey.armstrong@us.army.mil	1
Chris Villarreal	US Environmental Protection Agency	US Environmental Protection Agency Superfund Division (6SF-AT) 1445 Ross Avenue Dallas, TX 75202-2733	Office: 214-665-6758 villarreal.chris@epamail.epa.gov	2
Fay Duke	Texas Commission of Environmental Quality	Texas Commission on Environmental Quality TCEQ Environmental Cleanup Section II, Team 2 (MC-221) 12100 Park 35 Circle, Bldg D Austin, TX 78753	Office: 512-239-2443 fduke@tceq.state.tx.us	2 - most 4-eco
Dale Vodak	Texas Commission of Environmental Quality	Texas Commission on Environmental Quality 2916 Teague Drive Tyler, TX 75701	Office: 903-535-5147 dvodak@tceq.state.tx.us	1
Paul Bruckwicki	US Fish and Wildlife Service	US Fish and Wildlife Service PO Box 230 Karnack, TX 75661 (<i>mailing only</i>) Caddo Lake NWR 15600 FM 134 Karnack, TX 75661	Office: 903-679-9144 Cell: 903-407-0852 paul_bruckwicki@fws.gov	1
Barry Forsythe	US Fish & Wildlife Service EPA Liaison (6SF- LT)	US Fish & Wildlife Service EPA Liason (6SF-LT) 1445 Ross Avenue, Suite 1200 Dallas, TX 75202	Office: 214-665-8467 forsythe.barry@epa.gov	1 eco

Total external distribution for routine draft final (non eco) reports = 11



00043193

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

February 8, 2007

DAIM-BD-LO

Mr. Chris Villarreal
US Environmental Protection Agency
Superfund Division (6SF-AT)n
1445 Ross Avenue
Dallas, TX 75202-2733

Re: Final Modeling Report Derivation of Soil and Groundwater Concentrations Protective of
Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas,
Revision 1, February 2007

Dear Mr. Villarreal,

The above-referenced document is transmitted to you for your files.

Point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by
email at rose.zeiler@us.army.mil.

Sincerely,

A handwritten signature in black ink, reading "Rose M. Zeiler", is positioned below the "Sincerely," text.

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

Enclosure: Final Modeling Report, Revision 1, February 2007

Copies furnished:

Fay Duke, TCEQ, Austin, TX
Paul Bruckwicki, Caddo Lake NWR, TX
Cliff Murray, COE-Tulsa District, OK
John Lambert, COE – Tulsa District, OK
Praveen Srivastav, Shaw – Houston, TX



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

February 8, 2007

DAIM-BD-LO

Ms. Fay Duke
Texas Commission on Environmental Quality
Environmental Cleanup Section II (MC-221)
12100 Park 35 Circle, Bldg D
Austin, TX 78753

Re: Final Modeling Report Derivation of Soil and Groundwater Concentrations Protective of
Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas,
Revision 1, February 2007

Dear Ms. Duke,

The above-referenced document is transmitted to you for your files.

Point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by
email at rose.zeiler@us.army.mil.

Sincerely,

A handwritten signature in cursive script, reading "Rose M. Zeiler", is positioned below the word "Sincerely,".

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

Enclosure: Final Modeling Report, Revision 1, February 2007

Copies furnished:

Chris Villarreal, USEPA Region 6, Dallas, TX
Paul Bruckwicki, Caddo Lake NWR, TX
Cliff Murray, COE – Tulsa District, OK
John Lambert, COE – Tulsa District, OK
Praveen Srivastav, Shaw – Houston, TX

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
Comments from Chris Villarreal (EPA) by Roger W. Lee (USGS)						
1	General		I have read the subject report and find it to be well organized and thorough in predicting fate and transport of COCs from source areas on site to points of entry to Caddo Lake. However, there should be actual data available of surface water and ground water contamination to validate modeling predictions. These data are not considered nor provided in this document. The report provides sufficient information to evaluate models, but has left out a good bit of the chemistry and geochemistry of the site. Fate of COCs like chlorinated solvents rely on anaerobic biodegradation terms in the models as part of their chemical processing in the aquifers. However, no evidence of geochemistry of ground water is presented to support anaerobic conditions. If conditions are aerobic as they can be in shallow aquifers, no biodegradation of TCE would be observed and fate and transport modeling should not use a biodegradation term in the in model. This could affect predictions of TCE transport to streams.		<p>The stakeholders at LHAAP opted to use simple models for predicting fate and transport of the COCs at LHAAP. The models used; Domenico's equation and AT123D are analytical and semi-analytical tools that assume a homogenous settings. Field observations indicate a heterogeneous subsurface at LHAAP that may depart remarkably from the homogenous settings assumed during prediction of fate and transport of contaminants, therefore, calibration of these models is not practical. In addition, due to lack of groundwater data at the points of exposure, validation of the models is not possible.</p> <p>Two practical evidences suggest that there is some degradation at the sites. During the September 2004 data gap sampling event, geochemistry data were collected from LHAAP-58 (35A). The dissolved oxygen data in most of the monitoring wells showed values less than 1.0 mg/L. The highest was detected at 11.12 mg/L at well 35AWW01, but dropped to only 0.99 mg/L after less than 2 hours during the test. Redox values ranged greatly from -129 to 354. Second, cis-1,2-DCE and vinyl chloride were detected at some sites. These are daughter products of PCE and TCE which proves in itself that dechlorination occurred. On the other hand, recent study at LHAAP-16 shows that sulfate levels are elevated and there is no carbon to sustain significant reductive dechlorination under existing conditions. A study conducted by Geosyntec showed that even when TCE degradation was stimulated in the presence of lactate, vinyl chloride did not degrade, as indicated by a lack of ethene detection. VC degradation potentially may occur only when most of TCE and cis-1,2-DCE have dechlorinated, because the thermodynamics of reductive chlorination favors the higher chlorinated compounds. These conflicting phenomena demonstrate that not only is the geologic condition highly heterogeneous at LHAAP but the geochemistry is also highly heterogeneous. As such, the reductive dechlorination assumption used in the report may be valid for some sites and not valid for others. Based on current available data and lack of MNA geochemistry data, the reductive</p>	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					dechlorination assumption has been conservatively utilized. It is the intention of the Army to present the results of the current transport calculations for PCE, TCE, cis-1,2-DCE and VC at the sites involved (LHAAP-12, -29, -35A, -35B, -35C, -47, -48, -50 and -67) until such a time that additional data are available to validate the presence or absence of degradation on a site-specific basis. Additional comment from Robert Lee - Areas should be noted in text or map if chlorinated degradation is evident or not. See page 4-14 for new text.	
1	Section 3.0		Title should be "Modeling considerations for COCs at Select LHAAP Sites"	C	The title of the Section has been revised to reflect the comment.	
2	Table 3-1		TCA isomers are considered only at LHAAP-67. Is this their only occurrence on the site?		1,1,2-Trichloroethane (TCA) was detected at LHAAP-35A, -47 and -50. At two of these sites (LHAAP-47 and 50), the maximum detected concentrations were below the MCL. At LHAAP-35A, TCA was detected at concentrations above the MCL. The proportion of risk contributed by each COC for a specific site was one of the factors in the COC selection (Shaw, 2004a). The risk contributed by TCA at LHAAP-35A was minor compared with other contaminants that were modeled (trichloroethene, tetrachloroethene, 1-1, dichloroethene, RDX, and perchlorate), and therefore was not selected for modeling. Additional comment from Robert Lee - Response is fine but should be in text. See page 4-1 for new text.	
3		1st Paragraph	How was the decreasing trend for perchlorate determined? Please provide evidence and data to show this conclusion can be supported.		Historical perchlorate data for LHAAP-29 was evaluated and showed a general decreasing trend. Table 4-1 summarizes the perchlorate groundwater analytical data. Additional comment from Robert Lee - The question of how a decreasing trend was determined was not answered. Was a statistical evaluation used? Graph of time vs. perchlorate? A method should support the conclusion. The conclusion of decreasing trend was based on data in Table 4-1.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
4		3rd Paragraph	What analytical methods were used to establish initial contaminant concentrations in the soil?		<p>Analytical methods used to establish the initial contaminant concentrations were those analytical methods listed in the approved Final Work Plans for RI/FS at LHAAP prepared by Jacobs Engineering Group, Inc and Solutions to Environmental Problems, Inc., as follows:</p> <p>VOCs EPA Method 8260A SVOCs EPA Method 8270 Metals (except Hg) EPA Method 6010A Hg EPA Method 7471A Explosives EPA Method 8330 Pesticides/PCBs EPA Method 8080A Dioxins/Furans EPA Method 8290 Perchlorate EPA Method 314.0</p> <p>This information will be incorporated into the report.</p> <p>Additional comment from Robert Lee - Response is good, add to text.</p> <p>See page 4-3 for reference.</p>	
5		3rd Paragraph	Does this model code require boundary conditions or establish a hydrologic steady state? You might state how this differs from hydrologic models coupled with transport.		<p>The Domenico equation used here is under steady state condition. Since it is an analytical model and a non-exact solution which assumes homogeneous, isotropic, it does not require the stringent boundary conditions required by other numerical transport models. The source plume has to be defined in terms of its horizontal and vertical dimensions. The spreading of the plume in the vertical direction is limited by the aquifer's thickness. When the thickness of the source plume is less than the aquifer thickness, it would spread horizontally and vertically downwards until it reaches the entire thickness at which the vertical dispersivity is no longer active and the error function term with α_z in Equation 4-15 becomes unity. The horizontal distance at which the plume touches the bottom can be calculated (Domenico and Schwartz, 1998).</p> <p>Additional comment from Robert Lee - The response is ok, but the limits of the model should be discussed in the text.</p> <p>See page 4-12 for new text.</p>	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
6	Page 4-1		There should be included here a table of half-lives used with references.		This portion is a general description of the overall methodology used in the evaluation of the dilution factor. A list of half-lives and degradation rates with references has been presented for each individual site in the Appendices included in the report except those sites whose only COC is perchlorate which is assumed to have no degradation rate. Additional comment from Robert Lee - The response is ok, but when the half-lives are discussed in the text, refer to the attachment appendix pertinent to the discussion. See applicable Appendices for discussion.	
7	Page 5-2	4th Paragraph and elsewhere	Does the ground-water geochemistry show a low enough redox potential and low dissolved oxygen to support biodegradation of TCE? Without that specific data, it is difficult to support that the system is anaerobic and subject to reductive dechlorination. If aerobic conditions prevail, TCE should not have a biodegradation term in the fate and transport computations.	C	See response to comment no.1 Additional comment from Robert Lee - areas should be noted in text or map if chlorinated degradation is evident or not. See response to General Comment #1.	
8	Page 2-2	Appendix B	The half lives for TCE and VC should be reconsidered. TCE should not have a half life term if the system is aerobic. I could not find 3.4 years as a half life for VC in the Howard reference. They were 2 years and 8 years at a maximum for VC.	C	Please see response to comment no.1. The half life utilized for VC during the modeling was the average of the literature values. The model was rerun with a conservative half-life of 8 years to address field comment. Additional comment from Robert Lee - ok. A text revision is expected. See page 2-2 in Appendix B for new text.	
9	Page 2-3	Appendix B 2nd Paragraph	Koc is not applicable to perchlorate, but there is some sorption (Kd) for perchlorate, albeit small because of its relatively high aqueous solubility. The sorption process is different for perchlorate and relatively negligible but not because it is inorganic as stated.	C	The text has been revised for clarity. Koc is not applicable to perchlorate, but there is some sorption for perchlorate at a negligible value. When a substance is inorganic, there is no Koc involved. That is what this sentence was meant to state. It does not mean that perchlorate has no sorption process because it is inorganic. It still has a small Kd value that can be neglected. Additional comment from Robert Lee - ok. A text revision is expected. See page 2-3 in Appendix B.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
Comments from Alan Etheredge (TCEQ) by Charles D. Stone (Remediation Division)						
10	A.1	Table 1	Table 1 summarizes the various release sites and associated exposure pathway evaluations. This document address exposure pathways for each release site in its respective Section (see Table 1).	C	<p>A summary table of all the model parameters and input values has been provided for each site in the appendices. Model descriptions are provided in the main text. Site-specific parameter input values are described for each individual site. However, due to lack of these site-specific data, literature values were used.</p> <p>7Q2 value was derived based on daily discharge with 5-minutes interval obtained from the continuous record from December 1999 to March 2000. Since this is a short duration record of less than 5 years, a more stringent requirement of 10th percentile will be used as an estimate of 7Q2 as stipulated by TCEQ ("Determining 7Q2" in "Procedures to Implement the Texas Surface Water Quality Standards, January 2003," TCEQ), which is approximately 2.5 cfs, instead of 26 cfs used previously. The mixing concentration in the surface water has been re-calculated.</p>	
SECTION B: LHAAP-4						
11	B.1		Geologic, hydrostratigraphic and aquifer hydraulic information are not provided, as requested by TCEQ (2003). Minimum model simulation submittal requirements are not provided, as requested by the TCEQ (2003).	C	Section 2.2 in the main text portion has been revised to add more information about geology and hydrogeology of LHAAP. Jacobs RI reports and several cross-sections have been provided on a CD included with the document. Site geology and hydrogeology parameters for LHAAP-04 are described on Pg 2-1 to 2-2 of Appendix A to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). Aquifer hydraulic information (hydraulic conductivity, hydraulic gradient and flow direction) is provided on a site-by-site basis in the appendices.	
12	B.2		COC PCL determinations at LHAAP-4 are for perchlorate only. Modeling of the ^{GW} pathway for perchlorate is considered "not necessary" because the groundwater concentration in monitoring well 04WW01 of 3.98 µg/L reported in STEP (2003) did not exceed the Texas Class 1 Groundwater PCL of 17.0 µg/L (Sec 1.0, Appendix A, Subject Report).		We agree that perchlorate concentration at the source could be higher than 3.98 µg/L at 04WW01. However, back calculation using Domenico solution indicates a dilution factor of 1.119 (see attachment). This implies that the concentration at the source (180 feet north of well 04WW01) could be 4.45 µg/L which is still less than the groundwater MSC of 26 µg/L and less than the Texas Class 1 Groundwater PCL of 17.0 µg/L.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			<p>However, MW 04WW01 is located approximately 180 feet south of the acknowledged source in a direction that is lateral to, not along, the easterly groundwater gradient (e.g., Sec 1.0 & Figure 3A, Appendix A, Subject Report). Back calculation of the Domenico solution to the groundwater fate and transport equations (e.g., Domenico and Schwartz, 1997) using input parameter value assumptions commensurate with the location would indicate that <i>groundwater perchlorate concentrations closer to the LHAAP-4 may exceed the PCL and that a significant perchlorate plume appears to be present and migrating down gradient</i> from there.</p> <p>Additionally, current perchlorate concentrations in MW 04WW01 are not provided in the subject report.</p>		<p>The input parameters (hydraulic conductivity, hydraulic gradient, longitudinal and lateral length of the assumed plume, dispersivities, and aquifer thickness, distance to Goose Prairie Creek, etc) in the calculation are all site-specific or based on regulatory assumptions. Conservative assumption was made that the "plume" occupies the full thickness of the water bearing zone.</p> <p>The available perchlorate concentration information used in the calculation were those obtained from reports generated by the Jacob's Engineering Group in 2002 and 2003. The most recent perchlorate concentration in well 04WW01 was non-detect, the detection limit of which was 1.0 µg/L (Shaw E & I: Draft Final – Data Gap Investigation, July 2005).</p> <p>After further discussions with TCEQ, additional modeling was conducted in y-direction to demonstrate transport in that direction. This was done for sites LHAAP-4, -29, -47.</p>	
13	B.3		<p>VLEACHSM is used to simulate the leaching of perchlorate soil contamination to groundwater (Sec 2.1, Appendix A, Subject Report). Some assumed perchlorate chemical input parameter values used in the VLEACHSM simulations require revision:</p> <p><u>Henry's Law constant</u> - data regarding partitioning of perchlorate from the liquid phase into the vapor was not available (Sec 2.1.1, Appendix A, Subject Report). However, the value is expected to be small. <i>The recommended conservative value for the Henry's Law constant is zero (0.0).</i></p> <p><u>Air diffusivity</u> - similar to Henry's Law constant (above), <i>the recommended conservative value for air diffusivity is zero (0.0).</i></p> <p><u>Aqueous solubility</u> - solubility data were not available (Sec 2.1.1, Appendix. A, Subject Report). Perchlorate is an <i>ion</i>, and is completely soluble in water. The assumed</p>		<p>The input parameters for perchlorate in the model are conservatively small in values for Henry's Law constant, air diffusivity, and high solubility (50,000 mg/L). Had these parameter values been changed to the recommended values, the nature of the results would still remain the same.</p> <p>The perchlorate phase is currently not clear. The exact commensurate solubility cannot be identified at this moment. The solubility depends on the kind of perchlorate compound at</p>	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			<p>solubility greatly underestimates the actual solubility. VLEACH requires the solubility for a <i>solid phase</i> COC in the soil. While the subject report does not discuss the nature or origin of the perchlorate, <i>an appropriate perchlorate phase must be specified (e.g., ammonium perchlorate - for explosives and solid rocket motors, etc.) and a commensurate solubility assigned</i>. This should be reflected in the revised model simulation.</p> <p><u>Kd / degradation rate</u> - a typographical error appears likely (Sec 2.1.1, Appendix A, Subject Report) which couples these two separate parameters in the subject report. The discussion is interpreted to mean that both parameters are assigned a value of zero, with which the TCEQ concurs. Any other intended meaning should be clarified with the revised calculations.</p> <p><u>Dispersivities</u> - longitudinal dispersion (EQ A1, Appendix A, Subject Document) is provided, but not explained. Reference to an unavailable document (Dynamac Corporation, 1995) is not an acceptable substitute by which an evaluation for approval can be made. Additionally, the <i>arithmetic presented is incorrect</i> for both longitudinal and vertical dispersivities (EQs A1 & A2, Appendix A, Subject Report).</p> <p><u>Darcy velocity</u> - (presumably) for the VLEACHSM groundwater mixing calculation (EQ A3) uses an average <i>K</i> value that is "... based on the slug tests at LHAAP-04 and LHAAP-35. (Sec 2.1.1, Appendix A, Subject Document). However, Section 2.2.1 (Appendix A, Subject Document) indicates shallow underlying groundwater is a GWBU" ... <i>consisting of sand ranging from 2 to 5 feet ...</i>" in thickness. The <i>K</i> value derived from the slug test at LHAAP-04 is reported to be 3.5 x 10⁻⁵ cm/sec (Sec 2.1.1, Appendix A, Subject Document). <i>This value is inconsistent with a unit comprised of sand (e.g., Fetter, 1988, etc.) and is most</i></p>		<p>the site. It could range from 15,000 mg/L (potassium perchlorate) to 200,000 mg/L (ammonium perchlorate). The current value of 50,000 mg/L used in the model is within this range. Further, recalculation using zero values of Henry's Law constant and air diffusivity, and using 200,000 mg/L of solubility has shown that the difference in results is minimal, i.e., 75.94 mg/L versus 75.86 mg/L. This result has been documented in the final report.</p>	
				C	The error has been revised by adding "and" between "partition coefficient (kd)" and "degradation."	
				D	Dynamac Corporation was the company that developed VLEACHSM for the EPA's Robert S. Kerr Environmental Research Laboratory – Center for Subsurface Modeling Support (see the Reference List). Therefore this reference should be acceptable.	
				C	The equation A1 has a typo error. It has been corrected to: $\alpha_L = 2.554 \times 10^{-4} L_u^{3.811}$ This equation is provided in the VLEACHSM document (Dynamac Corporation, 1995).	
				D	The average hydraulic conductivity used for this site is actually 6.36 x 10⁻⁴ cm/sec and NOT 3.5 x 10⁻⁵ cm/sec as mentioned (see Pg 2-4, Appendix A). Because only one slug test data was available at LHAAP-04, additional test values from a nearby site (LHAAP-35A) were included to obtain the average value consistent with the formation type observed at the site. The soil type at the site is not pure sand, it is a combination of sand, clayey sand and silty sand. According to Fetter (1988), the range of hydraulic conductivity for silty sand and fine sand is from 10 ⁻³ to 10 ⁻⁵ cm/sec (Pg 80 of Fetter). The average value of hydraulic conductivity used for this site is therefore acceptable.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			likely a slug test performed either entirely or partially in the unit underlying the shallow sand GWBU. In lieu of available hydraulic aquifer test results, boring/well logs and other hydrostratigraphic information (see Item B. 1) <i>the Darcy velocity cannot be accepted by the TCEQ.</i>		Boring logs are included in Jacobs RI report provided in a CD with this report.	
			Based on the information provided and the discussion above, the submittal does not rise to the level necessary to support an ACL determination. Consequently, <i>the TCEQ cannot accept the results of the VLEA CHSM model simulations.</i>	D	Based on the above responses, model results obtained from VLEACHSM will be checked with the recommended input parameter values. However, the methodology and the relevant input parameters are considered adequate to support determination of protective values.	
14	B.4		AT123D is used to simulate groundwater fate and transport from the mixed groundwater simulated by VLEACHSM (see Item B.3) directly beneath the site to Goose Prairie Creek (Sec 2.2, Appendix A, Subject Report). Model submittal requirements requested by the TCEQ (2003) are not provided, including model domain, model calibration and model run data. Additionally, the details regarding the coupling of VLEACHSM and AT123D, also requested by the TCEQ (2003), are not provided in the subject report.		Model domain in this semi-analytical model (AT123D) includes the distance to Goose Prairie Creek (POE) which is described on Pg 2-4 of Appendix A. Laterally, the model domain extends 5 feet on both sides from the center line of the source. Vertically, it extends to the total thickness of the shallow water bearing zone which is 5 feet. Even though perchlorate was not detected in Goose Prairie Creek (i.e., can be regarded as zero concentration), there is no observed data at the POE (point of exposure at the interface of groundwater and surface water) in groundwater. Therefore there is no data to calibrate against when using AT123D. See also response to comment no.1 in reference to model calibration.	
			The submittal deficiencies discussed above, together with the inaccuracies inherent in the VLEACHSM model simulations (see Item B.3), prohibit further evaluation of	D	Shaw has provided model run data (model input and output files) on CD. The maximum mixing concentration of 78,000 µg/L derived from VLEACHSM was used conservatively as the source concentration. This value was converted to a release rate in (kg/hr) as required by AT123D. This is the only "coupling" between VLEACHSM and AT123D, unlike other numerical model where the changes of mixing concentration over time are inputs to the groundwater flow and transport model. The point has been clarified in the text on page 2-4 of Appendix A.	
					Strongly disagree.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			the AT123D model for LHAAP-4. As such, <i>the TCEQ cannot accept the results of the AT123D model simulations provided.</i>			
15	B.5		RUSLE (USDA, 1997) is used to evaluate the soil-to-sediment pathway using overland soil loss to Central Creek for the COC perchlorate. The origin and/or determination of numerous RUSLE input parameter values are not described or substantiated. Some parameter units conversions cannot be duplicated and appear to be incorrect (e.g., SL_{TOT}). The source of each model input value should appear on a table. All site-specific parameter input <i>values</i> associated with the Universal Soil Loss Equation, the Sediment Load equation (SL), and S_{sed} Soil must be referenced and explained.		All the input parameters are either generated within RUSLE software or determined by the guidance in the RUSLE documentation (USDA, 1996). The explanation of each parameter is provided in Pg 3-1 through 3-3 of Appendix A. The derivation of parameters can be attached to the revised report for better understanding and book keeping purposes. All the units of parameters are correctly used as directed by the guidance documents. SL_{tot} has a unit of kg/ac-yr, which is a correct unit (refer to USDA, 1996). Because some site-specific parameters are not available, values derived from neighboring or similar location were used. For example, the rainfall-runoff erosivity factor was not available for LHAAP site, so the value derived for Shreveport, Louisiana was used. Other unavailable site-specific data needed in the calculation were estimations based on professional judgment. Where professional judgment is used, the text will state so clearly.	
16	B.6		The surface runoff to surface water pathway is evaluated using a modification of the TRRP 24 watercourse mass balance relationship and 7Q2 flow data. 7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a <i>50% probability exceedance</i> 7Q2 value and shall require re-calculation.	C	7Q2 value was derived based on daily discharge with 5-minutes interval obtained from the continuous record from December 1999 to March 2000. Since this is a short duration record of less than 5 years, a more stringent requirement of 10 th percentile will be used as an estimate of 7Q2 as stipulated by TCEQ ("Determining 7Q2" in "Procedures to Implement the Texas Surface Water Quality Standards, January 2003," TCEQ), which is approximately 2.5 cfs, instead of 26 cfs used previously. The mixing concentration in the surface water has been re-calculated.	
SECTION C: LHAAP-12						
17	C.1		The use of the Domenico steady state solution to the groundwater advection-dispersion fate and transport used for predictive purposes should be calibrated using the transient solution. No calibration of the model system appears in this section of the subject report.		Domenico equation is an analytical model assuming homogeneous and isotropic settings. No matter how well the calibration will be (i.e., good matching of observed and simulated concentrations), the so-called calibrated parameters still cannot represent the true values. As such, calibration using analytical models are not recommended in practice . Furthermore, monitoring wells are not present at the downstream POE locations, therefore neither flow data (i.e.,	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					head) nor concentration data are available for calibration purposes. In addition, perchlorate was not detected in Central Creek (Shaw 2004, Technical Memorandum). While the value for perchlorate may be assumed to be nondetect (zero) in Central Creek, no results are available for perchlorate at the POE between groundwater and surface water. Therefore calibration using stream concentration would not be possible. Please reference response to comment no. C.2 attached to the Technical Memorandum dated February 2004. After additional discussions with TCEQ, Shaw performed additional model runs in y-direction to include downgradient wells for sites LHAAP-04, -29, and -47.	
18	C.2		A correction for longitudinal distance, x, to the POE that accounts for the restriction of actual potential vertical dispersion, α_x , <i>should be made</i> and described for the condition: $S_d=B$. This correction for x is not apparent and affects the groundwater transport DAF.	C	Domenico equation was programmed in Excel spreadsheet with consideration of using α_z restricted by the thickness of the aquifer. When the thickness of the source plume is less than the aquifer thickness, the plume would spread horizontally and vertically downwards until it reaches the entire thickness at which point the vertical dispersivity is no longer active and the error function term with α_z in Equation 4-15 becomes unity. The horizontal distance at which the plume touches the bottom can be calculated (Domenico and Schwartz, 1998). This consideration IS reflected in the calculation. Tables 1, 2, and 3 show the horizontal distance, Xp (the corrected x), at which the plume occupies the entire thickness and α_z cannot be considered in the equation after that point. In the current modeling, the source plume was conservatively assumed to occupy the entire thickness initially, therefore, Xp = 0 (a worst case scenario). The Final report text has been revised to include the above description.	
19	C.3		Source concentrations of TCE and perchlorate are calculated (using the tentative values [see C.2]) to be exceeded at the groundwater - Central Creek surface water interface. Hence, surface water dilution factors were calculated.	C	Noted.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
20	C.4		The calculated value of U_{gw} (30.24 ft/yr) is <i>not consistent</i> with the input parameter values described in subject report. TCEQ calculates a value of 49.9 ft/yr. <i>This apparent discrepancy should be resolved as it directly affects the surface water DF calculation (Q).</i>	C	Agree. The results have been revised.	
21	C.5		Recalculations of ^{sw} GW (see Item C.4) should be performed consistent with guidance provided in TCEQ (2002).	C	Groundwater concentration protective of surface water has been recalculated (see Response in C4).	
22	C.6		7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a different 7Q2 value and shall require re-calculation. Therefore, acceptance of the results and conclusions regarding the DF calculation for LHAAP-12 is deferred.	C	Because the current stream-discharge data only provide short-term records from December 1999 to March 2000. As stated in the response for comment no. B.6, the 10 th percentile should be used for 7Q2. However, in the current study, 7Q10 was used. This value is identical to 10 th percentile (i.e., 1.0 cfs). The text related to this section has been revised and the results have been checked.	
23	C.7		No other exposure pathway has been addressed in association with the LHAAP-12 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed.		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. See section 3.0 and Table 2-1.	
SECTION D: LHAAP-29						
24	D.1		AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of methylene chloride, 1,2-DCA, TCE and perchlorate from the source area to Central Creek, at a distance of approximately 312 feet away. The subject report lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results. In lieu of these data, the evaluation of the results of this modeling can not occur until a full and complete description and report of the simulation is received. Until	D	A. The distance from the source area to Central Creek is not 312 feet as mentioned in the comments. It is approximately 6,125 feet. B. The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 of Appendix C to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Central Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 2-1 of Appendix C. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix C). The potentiometric surface for this site is	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			such time, the results of the model can not be evaluated or accepted.		included as Figure 2. Basically, all the information for running AT123D is included in this Appendix C. C. Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model.	
25	D.2		The requested hydrogeologic information (see D.1) also must detail reasons why groundwater discharge to nearby Goose Prairie Creek surface water is not considered in the modeling.		As mentioned on page 1-1 in Appendix C, groundwater flow direction is toward southeast. The Closest surface water body downgradient of the source area is Central Creek. Available groundwater data does not indicate that groundwater would flow into Goose Prairie Creek, which is located to the north.	
26	D.3		7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the 10 th percentile as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a different 7Q2 value and shall require re-calculation. Therefore, acceptance of the results and conclusions regarding the DF calculation for LHAAP-29 is deferred	C	The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B6 and C6) for short term discharge records.	
27	D.4		No other exposure pathway has been addressed in association with the LHAAP-29 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. Please see comment response #23.	
SECTION E: LHAAP-35A (58)						
28	E.1		AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of 1,1 -DCE, TCE, PCE, RDX and perchlorate from the source area to Goose Prairie Creek, at a distance of approximately 6,319 feet away. The AT123D modeling report for LHAAP-35A (58) lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and	D	A. The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 of Appendix D to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Central Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 2-1, Appendix D. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix D). The potentiometric surfaces for this site are	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			specific simulation results (see Attachment A). Additionally, the TCEQ requests the digital input file and printed output file for the LHAAP-35A (58) simulations. The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.		shown in Figures 3A and 3B. Basically, all the information for running AT123D is included in Appendix D. B. Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model. C. Shaw has provided digital input and output files on a CD.	
29	E.2		VLEACHSM or "VLEACHM" (Sec 2.1.1, Appendix L, Subject Report) is used to "... obtain the leachate mixing concentration hydrograph ..." for bis(2-ethylhexyl)phthalate in groundwater at LHAAP-35A (58). This simulation comprises COC leaching from a source in the unsaturated zone, mixing of the leachate with underlying groundwater and transport of COC mass in saturated zone to location of POE. The VLEACH(?) modeling report for LHAAP-35A (58) lacks requisite information regarding the modeled simulation, including details regarding soil polygon data (for each polygon), COC properties, soil recharge information and aquifer properties, as well as the sources of the values. The use of VLEACH/VLEACHSM requires accompaniment of commensurate input information of model construction and model parameters (see for example Section 6.0, <i>Input Parameters</i> , VLEACH 2.2 (USEPA, 1997). Additionally, the TCEQ requests the digital input file (depending on model version) and printed output file for the LHAAP-35A (58) simulations. The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.	D	A. Typo error for VLEACHM has been corrected to VLEACHSM. B. The soil polygon is selected at the maximum soil concentration location. There is no need to use other polygons where soil concentrations are lower. COC and aquifer properties (source release, source area and depth, hydraulic conductivity, hydraulic gradient, recharge, dispersivities, chemical parameters etc) are described on page 2-1 to 2-2 of Appendix L. C. Shaw has provided digital input and output files on a CD.	
30	E.3		The COCs 1,1,2-TCA and VC and were not included in the model simulation. The precise reasons for their respective elimination is absent from the subject document. However, the reasons for their elimination	D	The reasons for not modeling these COCs are mentioned in 3 rd paragraph, Page 1-1 (Appendix D).	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			should be documented and included in the submittal			
31	E.4		RUSLE (USDA, 1997) is used to evaluate the soil-to-sediment pathway using overland soil loss to Central Creek for the COC perchlorate. The origin and/or determination of numerous RUSLE input parameter values are not described or substantiated. Some parameter units conversions cannot be duplicated and appear to be incorrect (e.g., SL_{TOT}). The source of each model input value should appear on a table. All site-specific parameter input <i>values</i> associated with the Universal Soil Loss Equation, the Sediment Load equation (SL), and Sed Soil must be referenced and explained.	D	<p>A. RUSLE (USDA, 1996; Toy and Foster, 1998) is used to evaluate the soil-to-sediment pathway using overland soil loss to Goose Prairie Creek and NOT Central Creek for the COC bis(2-ethylhexyl)phthalate, NOT perchlorate for Site 35A (58) as mentioned in the comments.</p> <p>B. All the input parameters are either generated within RUSLE software or determined by the guidance in the RUSLE documentation (USDA, 1996, Toy and Foster, 1998). The explanation of each parameter is provided on Pg 4-3 through 4-6 in the main text and on Page 2-1 to 2-3 in Appendix D. All the units of parameters are correctly used as directed by the guidance documents. SL_{TOT} has a unit of kg/ac-yr, which is a correct unit (refer to USDA, 1996). Because some site-specific parameters are not available, values derived from neighboring or similar location were used. For example, the rainfall-runoff erosivity factor was not available for LHAAP site, so the value derived for Shreveport, Louisiana was used. Other unavailable site-specific data needed in the calculation were an estimation based on professional judgment.</p>	
32	E.5		The soil-to-surface water exposure pathway for bis(2-ethylhexyl)phthalate was evaluated using an inappropriate value for 7Q2. 7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a <i>50% probability exceedance</i> 7Q2 value (Appendix L, Subject Report) and shall require recalculation. Therefore, acceptance of the results and conclusions regarding the soil-to-surface water exposure pathway for LHAAP-35A (58) is deferred.	C	The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B6 and C6) for short term discharge records.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
SECTION F: LHAAP-35B (37)						
33	F.1		<p>AT123D (ORNL, 1981) was used to simulate groundwater flow and contaminant transport of 1,1-DCE, TCE and PCE from the source area to Goose Prairie Creek at a distance of approximately 125 feet away.</p> <p>The AT123D modeling report for LHAAP-35B (37) lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-35B (37) simulations.</p> <p>The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.</p>		<p>A. The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix E to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Goose Prairie Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 2-1 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix E). The potentiometric surface for this site was not prepared but a plant site-wide potentiometric surface based on December 1998 water level measurement was used as mentioned on Page 1-1. Basically, all the information for running AT123D is included in Appendix E.</p> <p>B. Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model</p> <p>C. Shaw has provided digital input and output files on a CD.</p>	
34	F.2		No other exposure pathway has been addressed in association with the LHAAP-35B(37) site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. Please see comment response #23.	
SECTION G: LHAAP-35C (53)						
35	G.1		<p>AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of TCE and perchlorate from the source area to Central Creek, at a distance of approximately 300 feet away and Harrison Bayou, at a distance of approximately 658 feet away.</p> <p>The AT123D modeling report for LHAAP-35C (53) lacks requisite information regarding the modeled simulation,</p>		A. The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix F to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distances to Central Creek and Harrison Bayou, and the vertical distance (the thickness of the	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-35C(53) simulations. The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.		shallow water-bearing zone). This information is provided on page 1-1 and 2-1 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Tables 1 and 2 (Appendix F). The potentiometric surface for this site was not prepared but a plant site-wide potentiometric surface based on December 1998 water level measurement was used as mentioned on Page 1-1. Basically, all the information for running AT123D are included in this Appendix F. B. Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model	
36	G.2		RUSLE (USDA, 1997) is used to evaluate the soil-to-sediment pathway using overland soil loss to Central Creek for the COC perchlorate. The origin and/or determination of numerous RUSLE input parameter values are not described or substantiated. Some parameter units conversions cannot be duplicated and appear to be incorrect; in the case of SL_{TOT} , reference is made to a "Section 4.1.1" that does not exist. The source of each model input value should appear on a table. All site-specific parameter input <i>values</i> associated with the Universal Soil Loss Equation, the Sediment Load equation (SL), and ^{Sed} Soil must be referenced and explained. The TCEQ human health PCL value for perchlorate in sediment (C_{TOT}) used for this pathway should be checked for updated values.		A. All the input parameters are either generated within RUSLE software or determined by the guidance in the RUSLE documentation (USDA, 1996, Toy and Foster, 1998). The explanation of each parameter is provided on Pg 4-3 through 4-6 in the main text and on Page 3-1 to 3-6 in Appendix F. The derivation of parameters can be attached to the revised report for better understanding and book keeping purposes. All the units of parameters are correctly used as directed by the guidance documents. SL_{TOT} has a unit of kg/ac-yr, which is a correct unit (refer to USDA, 1996). Because some site-specific parameters are not available, values derived from neighboring or similar location were used. For example, the rainfall-runoff erosivity factor was not available for LHAAP site, so the value derived for Shreveport, Louisiana was used. Other unavailable site-specific data needed in the calculation were an estimation based on professional judgment. B. The TCEQ human health PCL value for perchlorate in sediment was obtained from the Table for Risk Reduction Program Rule, TNRCC, 2002.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
37	G.3		<p>The surface runoff to surface water pathway is evaluated using a modification of the TRRP 24 watercourse mass balance relationship and 7Q2 flow data.</p> <p>7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>1 0th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a <i>50% probability exceedance</i> 7Q2 value and shall require re-calculation.</p>		The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B6 and C6) for short term discharge records.	
SECTION H: LHAAP-46						
38	H.1		<p>AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of perchlorate from the source area to Goose Prairie Creek, at a distance of approximately 312 feet away.</p> <p>The AT123D modeling report for LHAAP-46 lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-46 simulations.</p> <p>The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.</p>		<p>The distance from the source to Goose Prairie Creek is approximately 3120 feet, NOT 312 feet stated in the comment.</p> <p>The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix G to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Goose Prairie Creek, the vertical distance (the thickness of the shallow water-bearing zone). These information are provided on page 2-1 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix G). The potentiometric surface for this site was not prepared but a plant site-wide potentiometric surface based on December 1998 water level measurement was used as mentioned on Page 1-1. Basically, all the information for running AT123D is included in this Appendix G.</p> <p>Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model.</p>	
39	H.2		Leachate modeling at LHAAP-46 is alluded to (Sec 2.2, Appendix L, Subject Report) in regards to Goose Prairie Creek "875 feet downgradient." This distance differs from that reported in Item H. 1. One sentence is devoted	D	The distance of 875 feet referenced here is the distance for surface soil to be transported on land surface to Goose Prairie Creek. The distance of 3120 feet mentioned in H.1 is the distance in groundwater from the source to Goose Prairie	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			to explaining the model and its results. The results are can not be accepted for reasons explained in Sec E (above).		Creek along the flowpath. This sentence in question substantiates the reason why leachate modeling of bis(2-ethylhexyl)phthalate is not necessary because leachate concentration at Site 35A (58) is less than MCL in groundwater even though the soil concentration is higher than that in Site 46 when the rest of the parameters are similar.	
40	H.3		Modeling of the soil-to-sediment model is similarly alluded to in Sec 2.2.2.1 (Appendix L, Subject Report) to which the comments in Sec E (above) apply.		All the input parameters are either generated within RUSLE software or determined by the guidance in the RUSLE documentation (USDA, 1996, Toy and Foster, 1998). The explanation of each parameter is provided on Pg 4-3 through 4-6 in the main text and on Page 2-7 to 2-9 in Appendix L. The derivation of parameters can be attached to the revised report for better understanding and book keeping purposes. All the units of parameters are correctly used as directed by the guidance documents. SL_{TOT} has a unit of kg/ac-yr, which is a correct unit (refer to USDA, 1996). Because some site-specific parameters are not available, values derived from neighboring or similar location were used. For example, the rainfall-runoff erosivity factor was not available for LHAAP site, so the value derived for Shreveport, Louisiana was used. Other unavailable site-specific data needed in the calculation were estimation based on professional judgment.	
41	H.4		The soil-to-surface water exposure pathway for bis(2-ethylhexyl)phthalate was evaluated using an inappropriate value for 7Q2. 7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The exposure pathway determination was calculated using a <i>50% probability exceedance</i> 7Q2 value (Appendix L, Subject Report) and shall require recalculation. Therefore, acceptance of the results and conclusions regarding the soil-to-surface water exposure pathway for LHAAP-46 is deferred	C	The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses in B6 and C6) for short term discharge records.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
42	H.5		No other exposure pathway has been addressed in association with the LHAAP-46 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed.		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. Please see comment response #23.	
SECTION I: LHAAP-47						
43	I.1		<p>AT123D (ORNL, 1981) is used to simulate groundwater flow and TCE, PCE, PCP, VC and perchlorate contaminant transport from the source area to Central Creek from differing distances.</p> <p>The AT123D modeling report for LHAAP-47 lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-47 simulations.</p> <p>The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.</p>		<p>The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix H to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Goose Prairie Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 2-1 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1. The potentiometric surface for this site was not prepared but a plant site-wide potentiometric surface based on December 1998 water level measurement was used as mentioned on Page 1-1. Basically, all the information for running AT123D are included in this Appendix H.</p> <p>Model calibration was not performed (see response to comment no. C.1) because AT123D is basically an analytical model.</p> <p>Shaw has provided digital input and output files on a CD.</p>	
44	I.2		RUSLE (USDA, 1997) is used to evaluate the soil-to-sediment pathway using overland soil loss to Central Creek for the COC perchlorate. The origin and/or determination of numerous RUSLE input parameter values are not described or substantiated. Some parameter units conversions cannot be duplicated and appear to be incorrect (e.g., SL_{TOT}). The source of each model input value should appear on a table. All site-specific parameter input values associated with the Universal Soil Loss Equation, the Sediment Load		All the input parameters are either generated within RUSLE software or determined by the guidance in the RUSLE documentation (USDA, 1996, Toy and Foster, 1998). The explanation of each parameter is provided on Pg 4-3 through 4-6 in the main text and on Page 2-10 to 2-14 in Appendix L. The derivation of parameters can be attached to the revised report for better understanding and book keeping purposes. All the units of parameters are correctly used as directed by the guidance documents. SL_{TOT} has a unit of kg/ac-yr, which is a correct unit (refer to USDA, 1996). Because some site-specific	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			equation (SL), and ^{Sed} Soil must be referenced and explained.		parameters are not available, values derived from neighboring or similar location were used. For example, the rainfall-runoff erosivity factor was not available for LHAAP site, so the value derived for Shreveport, Louisiana was used. Other unavailable site-specific data needed in the calculation were estimation based on professional judgment.	
45	I.3		The subject report indicates groundwater modeling to surface water DF mixing calculations were performed using 7Q2 low flow discharge of 26 cfs (Sec 4.2, Appendix H, Subject Report), based on "...flow shown in figure 9." No Figure 9 occurs in this Appendix. However, the 7Q2 value is similar to that used elsewhere on the reach. 7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). Therefore, DF calculations shall require recalculation. Acceptance of the results and conclusions regarding the soil-to-surface water exposure pathway for LHAAP-47 is deferred.	C	Figure 9 was inadvertently left out of the draft report. The figure has been included in the final report. The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B.6 and C.6) for short term discharge records.	
SECTION J: LHAAP-48						
46	J.1		AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of TCE from the source area to Central Creek, at an unspecified distance feet away. The AT123D modeling report for LHAAP-48 lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LH.AAP-48 simulations. The evaluation of the results of this modeling can not proceed until a complete description and report of the	D	Because Site 48 is located on both sides of the tributary of the Central Creek and the monitoring locations are very close to this tributary, it was assumed conservatively that the maximum concentrations of TCE and perchlorate occurred at the creek in groundwater (Page 2-1, Appendix I). Therefore no groundwater modeling was performed. The report mistakenly mentions that AT123D was used (Page 1-1 of Appendix I). However, the mixing concentrations in the creek indicate levels lower than MCLs.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.			
47	J.2		The surface water mixing calculations were performed appear in Appendix L. 7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). The 7Q2 value used in the exposure pathway mixing calculation must be confirmed as appropriate and may require re-calculation.	C	The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses in B6 and C6) for short term discharge records.	
48	J.3		No other exposure pathway has been addressed in association with the LHAAP-48 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed.		<p>A. Correction for Sec 2.3.1, Page 2-9, Appendix L: VLEACHM has been corrected to VLEACHSM; bis(2-ethylhexy)phthalate has been corrected to PCE and vinyl chloride.</p> <p>B. PCE and VC in soil were detected at elevated concentrations, therefore VLEACHSM modeling was performed to identify the leachate concentration contributing to groundwater along this exposure pathway. The pathway from groundwater to surface water based on leachate was incomplete due to very low mixing concentrations. Another exposure pathway is the transport of PCE and VC along land surface by erosion. This pathway has been evaluated in terms of PCE and VC concentrations protective of sediment and surface water (see Page 2-10 through 2-14, Appendix L)</p>	
SECTION K: LHAAP-50						
49	K.1		<p>AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of TCE, PCE, VC, 1,2-DCA and perchlorate from the source area to Goose Prairie Creek, at a distance of approximately 132 feet away.</p> <p>The AT123D modeling report for LHAAP-50 lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size,</p>		The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix J to the extent of supporting the model (please reference response to comment No. C.3 attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Goose Prairie Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 1-1 and 2-1 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives,	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			<p>source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-50 simulations.</p> <p>The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.</p>		<p>partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix J). The potentiometric surface map based on September 2000 water level measurement for this site was not attached in the report but will be furnished in the final report. Basically, all the information for running AT123D is included in this Appendix J. However, more detail description of the concerned subjects will be added to the report as deemed necessary.</p> <p>Model calibration was not performed (see response to comment no. C1) because AT123D is basically an analytical model.</p> <p>Shaw has provided digital input and output files on a CD.</p>	
50	K.2		<p>The subject report indicates groundwater modeling results in exceedances of TCE, PCE, VC, 1,2-DCA and perchlorate at the surface water POE. Therefore, surface water DF mixing calculations were performed. However, no details, calculations or other relevant information regarding the calculations is provided.</p> <p>7Q2 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). Therefore, if the exposure pathway DF determination was calculated using a <i>50% probability exceedance</i> 7Q2 value, the DF determination shall require re-calculation</p>	C	<p>A. Detailed mixing calculation has been added to the Appendix.</p> <p>B. The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B6 and C6) for short term discharge records.</p>	
51	K.3		No other exposure pathway has been addressed in association with the LHAAP-50 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed.		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. Please see comment response #23.	
SECTION L LHAAP-67						
52	L.1		AT123D (ORNL, 1981) is used to simulate groundwater flow and contaminant transport of 1,1 -DCE, 1,2-DCA, 1,1,1 -TCA, 1,1,2-TCA and TCE from the source area to Central Creek, at a distance of approximately 867 feet		The geology and hydrogeology parameters (hydraulic conductivity, hydraulic gradient etc) are described in the main text and on page 2-1 in Appendix K to the extent of supporting the model (please reference response to comment No. C.3	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			<p>away.</p> <p>The AT123D modeling report for LHAAP-67 lacks requisite information regarding the modeled simulation, including: geology, hydrology, model dimensionality, potentiometric map of model domain, aquifer size, source area size, source release type and rate, model calibration information for groundwater flow and chemical transport throughout the model domain, and specific simulation results (see Attachment A). Additionally, the TCEQ request the digital input file and printed output file for the LHAAP-67 simulations.</p> <p>The evaluation of the results of this modeling can not proceed until a complete description and report of the simulation is received. In lieu of these data, the results of the model can not be evaluated nor accepted.</p>		<p>attached to the Technical Memorandum dated March 2004). The model dimensionality for AT123D includes the distance to Goose Prairie Creek, the vertical distance (the thickness of the shallow water-bearing zone). This information is provided on page 1-1, 2-1 and 2-2 in the appendix. The source area, source depth, release time, chemical properties (dispersivity, half-lives, partition coefficients, etc) are mentioned on page 2-1 and listed in Table 1 (Appendix K). The potentiometric surface map based on September 2000 water level measurement for this site was not attached in the report but will be furnished in the final report. Basically, all the information for running AT123D is included in this Appendix K.</p> <p>Model calibration was not performed (see response to comment no. C.1) because AT123D is basically an analytical model.</p> <p>Shaw has provided digital input and output files on a CD.</p>	
53	L.2		<p>The subject report indicates groundwater modeling results in exceedances of 1,2-DCA, 1,1,1 - TCA, 1,1,2-TCA and TCE at the surface water POE. Therefore, surface water DF mixing calculations were performed using 7Q10 low flow discharge of 5.0 cfs (Sec 3.2, Appendix K, Subject Report).</p> <p>However, 7Q10 determinations in streams for which long-term, daily discharge data are not available must be calculated using the <i>10th percentile</i> as an estimate of 7Q2 (TCEQ, 2002). Based on figure 2 (Appendix K, Subject Report), the <i>10th percentile</i> of 7Q2(10) is 1.0 cfs. Therefore, all exposure pathway DF determinations shall require re-calculation.</p>	C	The magnitude of 7Q10 has been revised based on TCEQ's requirements (refer to responses to comments nos. B6 and C6) for short term discharge records.	
54	L.3		No other exposure pathway has been addressed in association with the LHAAP-67 site. The subject report should document the specific reasons for which analysis of the other exposure pathways were not completed.		Based on the human health risk assessment, none of the COCs in soil were determined to have an unacceptable risk (Shaw's Technical Memorandum, March 2004), therefore the only exposure pathway is groundwater to surface water. Please see comment response #23.	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
SECTION M: CUMULATIVE COC LOADING TO CENTRAL CREEK. GOOSE PRAIRIE CREEK AND CADDO LAKE						
55	M.1		<p>Release sites LHAAP-4, LHAAP-35A (58), LHAAP-35B (37), LHAAP-46, LHAAP-47 and <i>LHAAP-50</i> represent exposure pathways to Goose Prairie Creek. Sites LHAAP- 12, LHAAP29, LHAAP-35C (53), LHAAP-48 and LHAAP-67 represent exposure pathways to Central Creek. Specifically, the soil-to-creek sediment, soil-to-surface water and groundwater-to- surface water pathways have been evaluated. Impacts to Goose Prairie Creek and to Central Creek from various sources through various exposure pathways have been documented; each pathway from each release having been evaluated <i>individually and independently</i> from all other single evaluations.</p> <p>However, while each individual pathway evaluation may eventually be shown to not exceed respective surface water PCLs, the <i>cumulative effect of numerous pathways</i> to Goose Prairie Creek, <i>whose 7Q2 discharge remains constant</i> in a reach, can result in PCL exceedances in <i>Caddo Lake</i>.</p> <p>No analysis of the cumulative effects of COC loading from all combined creek-specific pathways to Caddo Lake has been performed (in Subject Report).</p>		<p>This comment is correct if pollutants from each site are delivered along each pathway into THE SAME location at the creek (Central Creek or Goose Prairie Creek). Then the cumulative effect of numerous pathways has to be evaluated with the same 7Q2 flow in the creek to derive the mixing concentration. However, these pathways enter the creek(s) at different locations, some upstream and some downstream, NOT at the same location. In this case, pollutants entering at upstream location would be diluted due to mixing and also dispersed along the creek flowing downstream before they reach another location where more pollutants from other pathways are discharged into the stream. Therefore, accumulating all the pollutant concentrations from different pathways and using the 7Q2 flow to evaluate the mixing concentration will undoubtedly underestimate the dilution factor (DF).</p> <p>To be more accurate, one of the sophisticated surface water quality models such as SMS (surface water modeling system), WASP5, HSPF, QUAL2E, CE-QUAL-W2 or BASIN3 has to be applied. These models can cope with point source or non-point source loadings from different pathways at different locations. The cumulative effect of COC loading can thus be more accurately evaluated at Caddo Lake. However, the purpose of the modeling report was to evaluate the impact of releases from individual sites to nearby surface water. The assessment of cumulative effect on Caddo Lake is outside the scope of this document.</p>	
56	M.2		<p>The TCEQ requests that all appropriately-revised exposure pathway analyses (see above) be analyzed further as follows:</p> <ol style="list-style-type: none"> 1. Sum (cumulatively) revised mass loading for each applicable COC (see above) for each exposure pathway from each site leading to Goose Prairie Creek (see Item M. 1) with the appropriate, revised 7Q2 for Goose Prairie Creek. Compare final cumulative COC concentration in Goose Prairie 		See response to comment M.1.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			Creek to the applicable surface water standard for Caddo Lake. 2. Repeat process for Central Creek.			
SECTION N REFERENCES						
			<p>Domenico P.A. and Schwartz F.W. 1997 <i>Physical and Chemical Hydrogeology</i>, John Wiley & Sons, New York, 506 pp.</p> <p>Fetter C.W. 1988 <i>Applied Hydrogeology</i>, Macmillan Publishing Co., New York, 592 pp.</p> <p>ORNL 1981 ATJ23D: <i>Analytical Transient One-, Two- and Three-Dimensional Simulation of Waste Transport in the Aquifer System</i>, ORNL-5602, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN.</p> <p>STEP 2003 <i>Draft Final Project Report: Plant- Wide Perchlorate Investigation, Longhorn Army Ammunition Plant, Karnack, Texas - Volume 1</i>, Solutions to Environmental Problems, Inc., March.</p> <p>TCEQ 2002 <i>Procedures to Implement the Texas Surface Water Quality Standards</i>, RG- 194, Texas Commission on Environmental Quality, Austin, TX, 187 pp.</p> <p>TCEQ 2003 <i>Draft Technical Memorandum: Modeling Approach for Derivation of Soil and Groundwater concentrations Protective of Surface water and Sediment; Longhorn Army Ammunition Plant, Karnack, Texas; October 2003</i>, December 19, 2003. (Reproduced in Attachment A)</p> <p>USDA 1997 <i>Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (R USLE)</i>, Agriculture Handbook</p>		These are references given by Chuck Stone for his comments.	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			703, U.S. Department of Agriculture, Agricultural Research Service, Washington D.C., 4.04 pp. USEPA 1997 <i>VLEACH: A One-Dimensional Finite Difference Vadose Zone Leaching Model</i> , U.S. Environmental Protection Agency, ORD, CSMoS, Ada, OK.			
Comments from Kristian Mauricio by Charles D Stone						
SECTION A: TOPSOIL CONCENTRATION PROTECTIVE OF SURFACE WATER AND SEDIMENTS						
57	A.1		Each location at which ACLs for this model are needed should be plotted on a scaled site- wide map <i>and</i> on a scaled close-up map of a portion of the site-wide map. Nearby features such as ecological and/or human health receptors should be clearly resolved on the scaled detail maps		Modeled environmental sites are shown on a site-wide map (Figure 1 of each appendix). Actual areas being modeled, with streams where applicable, are included in appendices as well. Human health exposure is in Caddo Lake, a source of drinking water, however, it was agreed upon by the regulators and the Army that the modeling would be based on meeting ARARs at the nearby creeks.	
58	A.2		A summary table of all model parameters and their model input values should be included with the model description. The source of each model input value also should appear on the table. All site-specific parameter input values associated with the Universal Soil Loss Equation (USLE), the Sediment Load equation (SL), and Sed501 (?) must be referenced and explained.		A summary table of all the model parameters and input values has been provided for each site in the appendices. Model description is provided in the main text. Site-specific parameter input values associated with the Universal Soil Loss Equation (USLE), the Sediment Load equation (SL) are described for each individual site. However, due to lack of these site-specific data, literature values were used.	
59	A.3		Parameter input values used to calculate ^{SW} Soil should be summarized in a table that describes how the values were determined. Stream discharge values measurement methods should be described. The source of runoff, Kd, and all other values must be documented.		These values have been referenced and explained in more detail. For a one year period, approximately between December 1999 and December 2000, data collection instruments were placed in the three major streams on Longhorn AAP; Harrison Bayou, Central Creek and Goose Prairie Creek. On each stream, two data recording stations were installed, one upstream and one downstream. At each recording station, a profile line of the streambed was surveyed at right angles to the general stream flow collecting x, y, and z data for each survey point. Each station consisted of a data logger for collection and storage of the data, a measurement device that included a transducer for	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					the measurement of water depth, and a radar-type device capable of recording water velocity. The equipment was from ISCO and was capable of recording depth and velocity of the water. A data logger was connected to each transducer with information retrieved every one to two months. The measurements were collected by Jacobs Engineering in support of an installation-wide modeling report that was generated by the U.S. Army Corps of Engineers, Engineering Research and Development Center, Waterways Experiment Station.	
60	ATTACH-MENT A		<p>Copy of the following reference: TCEQ 2003 <i>Draft Technical Memorandum: Modeling Approach for Derivation of Soil and Groundwater concentrations Protective of Surface water and Sediment; Longhorn Army Ammunition Plant, Karnack, Texas; October 2003</i>, December 19, 2003.</p> <p>Sec A <u>Topsoil Concentration Protective of Surface Water and Sediments</u></p> <p>Sec B <u>Subsurface Soil Concentration Protective of Groundwater</u></p> <p>Sec C <u>Groundwater Concentration Protective of Surface Water (^{GW}SW)</u></p>			
SECTION B: SUBSURFACE SOIL CONCENTRATION PROTECTIVE OF GROUNDWATER						
61	B.1		The location of each area subject to this Tier 3 modeling effort shall be clearly plotted on a site-wide map <i>and</i> on a scaled enlargement showing actual areas being modeled, potential receptor details (e.g., streams, ecological features, <i>etc.</i>) and other relevant landmarks.		Modeled environmental sites are shown on a site-wide map (Figure 1 of each appendix). Actual areas being modeled showing streams where applicable are included in appendices as well.	
62	B.2		The origin and value of all parameter input values should be fully discussed and summarized in a table with references. Field documentation for a reference pedologic section at each model location is expected. Documentation for the origin of values of Kd, foc and COC physico-chemical properties should be included. Test methods used to determine site-specific parameter		See response to comment No. 59, A.2	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			values must be standardized procedures (e.g., ASTM) and be fully described.			
63	B.3		<p>Each VLEACH simulation must have a summary table of variable values for the <i>Simulation Data</i> and the <i>Polygon Data</i>. Justification of the values should be included. VLEACH runs should progress with sufficiently small timesteps to resolve meaningful trends and with a sufficiently long simulation length to reach steady state.</p> <p>Actual printouts of the results of each simulation run should be included in an Appendix. A summary of each VLEACH run should be presented in a table form within the body of the discussion. The predicted groundwater concentrations through time for each simulation location should be plotted and presented in the discussion.</p>		<p>Simulated data and polygon data have been provided for each site in the respective appendices. Many parameters used were literature values due to lack of site-specific tests.</p> <p>VLEACHSM results have shown a meaningful trend, especially peak concentrations at certain location have been revealed. In the current modeling, the peak mixing concentration was used conservatively. For VLEACH (or VLEACHSM), there is no "steady-state" to achieve, every time step is under equilibrium state among the three phases (liquid, solid and gaseous).</p> <p>Shaw has provided digital input and output files on a CD.</p>	
SECTION C: GROUNDWATER CONCENTRATION PROTECTIVE OF SURFACE WATER (^{GW} SW)						
64	C.1		LHAAP indicates it will use AT123D to perform long-term flow and transport modeling of groundwater and its interaction with surface water bodies.		Noted	
65	C.2		LHAAP should develop a <i>site-wide</i> flow model whose domain encompasses the entirety of the base and include all adjacent water bodies and potential receptors. <i>The flow model must be fully calibrated, verified and validated prior to performing any transport modeling.</i>		<p>Please see response to comment no. 34, C.2 attached to the Technical Memorandum dated March 2004.</p> <p>EPA, TCEQ agreed previously that simple models should be used for this purpose. 3-D numerical modeling was not considered necessary by the stakeholders.</p> <p>A site-wide flow model has to be a 3-dimensional numerical model such as MODFLOW. Only under such application can the model be calibrated. However, more detail site geology, hydrogeology and surface water investigation have to be conducted due to the heterogeneity of the sites. Surface water flow discharge would have to be measured continuously for at least another 5 years.</p>	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
66	C.3		The domain hydrogeology should be described in detail using available subsurface data. Hydrostratigraphy, aquifers, hydraulic divides, zones of saturation, stratigraphic variations, hydraulic interconnectivities, surface water interactions, appropriate boundary conditions, <i>etc.</i> must be identified and described completely. Assignment of all hydrogeologic parameter values must be validated and described. A summary table of all model parameter values should be presented		Please see response to comment no. 35, C.3 attached to the Technical Memorandum dated March 2004. The geology and hydrogeology parameters were described in the report to the extent of supporting the models.	
67	C.4		The flow model must be fully calibrated. Details of the calibration process should be described. Starting parameter values and calibrated values must be listed for comparison. Calibration statistics are expected.		A flow model was not planned, see response to comment no. 36, C.4 attached to the Technical Memorandum dated March 2004. Model calibration can only be performed when the site geology, hydrogeology and hydrology is fully investigated and the model used is a numerical model. Any attempt to calibrate an analytical model that assumes homogenous and isotropic settings is meaningless because no matter how well the calibration shows, the heterogeneity of the site may yield very different flow and transport results.	
68	C.5		The transport modeling should proceed only after the flow model has been calibrated, verified and validated. The transport model should account for all known contaminant sources, including those identified in Sec B. The maximum groundwater contaminant concentrations calculated from the VLEACH modeling in Sec B must be used as continuous source concentrations in the AT123D model. The continuous source concentrations must be incorporated into the AT123D model at each respective modeling location		Please see response to comment no. 37, C.5 attached to the Technical Memorandum dated March 2004. Simple analytical models such as VLEACHSM, AT123D, Domenico's equation cannot be used for calibration due to the reason mentioned in response to comment no. C.4. The maximum groundwater contaminant concentrations calculated from VLEACHSM were used as continuous sources or instantaneous sources, depending on each site situation very conservatively. The source concentrations do not need to be incorporated into AT123D at each respective modeling location. Conservatively, only the maximum concentration at its respective location needs to be incorporated into AT123D. There are two reasons: first, though we can input source concentration varied with time, we cannot input different concentration at different location in AT123D. We can only input a rate of release converted from a concentration value in the source area with source length, source width and source	

Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					depth. In the current modeling, the maximum concentration was used. This was a very conservative consideration.	
69	C.6		AT123D should be used to report the maximum predicted concentrations of each COC plume that contacts surface water bodies at the groundwater-surface water interface. Similarly, the maximum dissolved COC concentrations should be reported at all other points of exposure and potential receptors (e.g., wet lands, etc.).		The maximum predicted concentration of each COC at the interface of groundwater and surface water and at other points of exposure was used.	
70	C.7		All transport model inputs should be described in the text and summarized in a table		All the transport model inputs for each respective site are described in each appendix and are summarized in a table.	
71	C.8		AT123D output should be described individual for each dissolved COC plume within the model domain and all modeled groundwater plume-surface water body interaction should be discussed in detail using scaled maps and isoconcentration lines. All AT123D output data should be organized and summarized in the text. All actual AT123D output data should be organized and annotated in an Appendix		AT123D outputs are presented and described for each site in the respective appendices. The modeled groundwater plume – surface water interaction is also presented for each site in the respective appendices. However, construction of isoconcentration lines is not possible and not necessary. Shaw has provided digital input and output files on a CD.	
72	C.9		Dilution factors applied to groundwater at the surface water interfaces should be calculated at each interface location using the methods described in TRRP 24 (<i>Determining PCLs for Surface Water and Sediment</i>). Dilution factors should be calculated separately for each individual groundwater-surface water interface location. Discussion and calculations of each dilution factor is expected.		Dilution factors applied to groundwater at the surface water interfaces were calculated at each interface location using the methods described in TRRP 24 (<i>Determining PCLs for Surface Water and Sediment even though Longhorn is still under the old rules</i>). Dilution factors were calculated separately for each site at groundwater-surface water interface location. However, calculation for different location at one individual site is not necessary because we used the maximum concentration on the center line of the plume at the groundwater – surface water interface. That is a conservative approach. Other locations would only yield concentration less than the maximum concentration.	
ADDITIONAL COMMENTS IN AN EMAIL FROM FAY DUKE, TCEQ						

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
73			<p>Subject: Draft Minutes, Meeting to Resolve TCEQ Comments on Draft Final Modeling Report, Longhorn Army Ammunition Plant (LHAAP)</p> <p>Location of Meeting: TCEQ Office, Austin, TX</p> <p>Date of Meeting: July 06, 2006, 8:00 AM – 12:30 Noon</p> <p>It was agreed that Shaw will expand the geological/hydrogeological discussion in the main part of the report and add one or two representative cross-sections to the report. On a site-specific level, references will be provided to Figures in Jacobs reports.</p> <p>These references already exist in the report, but Shaw will review to make sure that there are no omissions.</p> <p>Additionally, Shaw will provide the Jacobs RI reports on a CD to allow Chuck Stone easy access to the cross-sections and other figures.</p> <p>Shaw will reference sources for values of modeling parameters where they are missing. Shaw will also provide TCEQ a copy of the Dynamac report which was the source of dispersivity values used in the modeling.</p> <p>Shaw will add text to clarify instances where certain output values of VLEACHSM are input to AT123D, and mention those values.</p> <p>A middle ground was suggested by Chuck Stone in a subsequent phone call to Song-Kai Yan, to perform additional runs of models in the Y-direction. This will allow TCEQ to compare actual versus predicted concentrations in monitoring wells in the lateral direction from the source. This may not be possible at every site due to lack of wells in the appropriate directions.</p> <p>Fay Duke suggested that Shaw compare the</p>		<p>All these issues have been addressed in the responses to preceding comments for LHAAP-29.</p> <p>The groundwater flow direction did not change significantly and thus the model was not rerun.</p>	

**Compilation - Response to Comments on
Draft Final Modeling Report: Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment (May 2005);
Longhorn Army Ammunition Plant, Karnack, Texas
June 2006**

Reviewers: Chris Villarreal with Roger W. Lee, U.S. Geological Survey and Alan Etheredge with Charles D. Stone (TCEQ)

Respondents: Song Kai Yan, Agnes Mayila and Praveen Srivastav, Shaw Environmental, Inc.

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 #	Page/Section	Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
			groundwater flow direction used for LHAAP-29 in the Modeling Report with a more recent groundwater map included in the evaluation report for the site, and adjust the model accordingly.			

FINAL
MODELING REPORT
DERIVATION OF SOIL AND GROUNDWATER CONCENTRATIONS
PROTECTIVE OF SURFACE WATER AND SEDIMENT
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



Prepared for
U.S. Army Corps of Engineers
Tulsa District
1645 South 101st Avenue
Tulsa, Oklahoma

Prepared by
Shaw Environmental, Inc.
3010 Briarpark Drive, Suite 4N
Houston, Texas 77042

Contract Number DACA56-94-D-0020
Task Order No. 0109

Revision 1
February 2007

Table of Contents

List of Tables	ii
List of Figures	ii
List of Appendices	ii
Acronyms and Abbreviations	iii
1.0 Introduction	1-1
2.0 Physical Setting	2-1
2.1 Surface Hydrology	2-1
2.2 Geology and Hydrogeology	2-1
3.0 Modeling Considerations for Chemicals of Concern at Select LHAAP Sites	3-1
3.1 Soil	3-2
3.2 Groundwater	3-2
4.0 Development of Protective Medium-Specific Concentrations for Chemicals of Concern	4-1
4.1 Medium-Specific Concentration	4-1
4.2 Analytical Models	4-2
4.2.1 Surface Soil Concentrations Protective of Sediment and Surface Water	4-3
4.2.1.1 Calculation for MSC-Soil-Sediment (^{Sed} Soil MSC)	4-3
4.2.1.2 Calculation for MSC-Soil-Surface Water (^{SW} Soil MSC)	4-7
4.2.2 Subsurface Soil Concentrations Protective of Groundwater	4-10
4.2.3 Groundwater Concentrations Protective of Surface Water	4-11
5.0 Modeling Results	5-1
5.1 LHAAP-04	5-1
5.2 LHAAP-12	5-2
5.3 LHAAP-29	5-2
5.4 LHAAP-35A(58)	5-2
5.5 LHAAP-35B(37)	5-3
5.6 LHAAP-35C(53)	5-3
5.7 LHAAP-46	5-3
5.8 LHAAP-47	5-4
5.9 LHAAP-48	5-4
5.10 LHAAP-50	5-5
5.11 LHAAP-67	5-5
5.12 Comparison of Modeling Results to Recent Studies	5-5
6.0 Additional Evaluations of Chemicals in Soil at LHAAP-35A(58), -46, and -48	6-1
6.1 LHAAP-35A(58)	6-1
6.2 LHAAP-46	6-1
6.3 LHAAP-48	6-2
7.0 Conclusions	7-1
8.0 References	8-1

List of Tables

Table 3-1	Rationale for Selection of Chemicals of Concern
Table 4-1	Perchlorate Analytical Data – LHAAP-29 Selected Shallow Monitoring Wells
Table 4-2	Input Parameters and Results for Soil Concentrations Protective of Sediment and Surface Water Calculations
Table 4-3	Rainfall/Runoff Erosivity (R Factor), Shreveport, Louisiana
Table 4-4	Input Parameters for Modeling Soil Concentrations Protective of Groundwater using VLEACHSM
Table 5-1	Summary of Modeling Results
Table 6-1	Summary of Additional Modeling of Chemicals in Soil at LHAAP-35A(58), -46, and -48

List of Figures

Figure 1-1	Area Map – Modeling Report
Figure 2-1	Longhorn Army Ammunition Plant with Surface Water Drainage Systems
Figure 3-1	Environmental Sites – Modeling Report
Figure 4-1	Isoerodent Map of Eastern United States – Modeling Report
Figure 4-2	Schematic Description of Domenico's Model

List of Appendices

Appendix A	LHAAP-04, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Soil and Groundwater
Appendix B	LHAAP-12, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek
Appendix C	LHAAP-29, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek
Appendix D	LHAAP-35A(58), Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Groundwater
Appendix E	LHAAP-35B(37), Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek
Appendix F	LHAAP-35C(53), Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek or Harrison Bayou
Appendix G	LHAAP-46, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Groundwater
Appendix H	LHAAP-47, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Soil and Groundwater
Appendix I	LHAAP-48, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek from Groundwater
Appendix J	LHAAP-50, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Groundwater
Appendix K	LHAAP-67, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek
Appendix L	Additional Evaluations of Chemicals in Soil at LHAAP-35A(58), -46, and -48
Appendix M	Creeks Survey and Water Elevation Data

Acronyms and Abbreviations

<i>A</i>	estimated average annual soil loss
ac	acre
ASTM	ASTM International (formerly American Society for Testing and Materials)
AT123D	Analytical Transient One-, Two-, and Three-Dimensional
bgs	below ground surface
<i>C</i>	cover management factor
cm ³ /g	cubic centimeters per gram
COC	chemical of concern
DCA	dichloroethane
DCE	dichloroethene
DF	dilution factor
<i>E</i>	energy
ft/yr	feet per year
ft ³ /sec	cubic feet per second
g/cm ³	grams per cubic centimeter
g/cm ³	grams per cubic centimeter
GWP	protective of groundwater
<i>I</i>	intensity
IAL	interim action level
Jacobs	Jacobs Engineering Group, Inc.
<i>K</i>	soil erodability factor
kg/L	kilogram per liter
kg/yr	kilogram per year
<i>L</i>	slope length factor
lb/ac	pound(s) per acre
LHAAP	Longhorn Army Ammunition Plant
MCL	maximum contaminant level
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MSC	medium-specific concentration
NAS	National Academy of Sciences
OA	other area
<i>P</i>	support practice factor
PCA	tetrachloroethane

Acronyms and Abbreviations (continued)

PCE	tetrachloroethene
PCP	pentachlorophenol
POE	point of entry
<i>R</i>	Rainfall-runoff erosivity factor
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RUSLE	Revised Universal Soil Loss Equation
<i>S</i>	slope steepness factor
SDR	sediment delivery ratio
Shaw	Shaw Environmental, Inc.
TCA	trichloroethane
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resource Conservation Commission
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
VC	vinyl chloride
VLEACHSM	Vadose Zone Leaching and Saturated Zone Mixing

1.0 Introduction

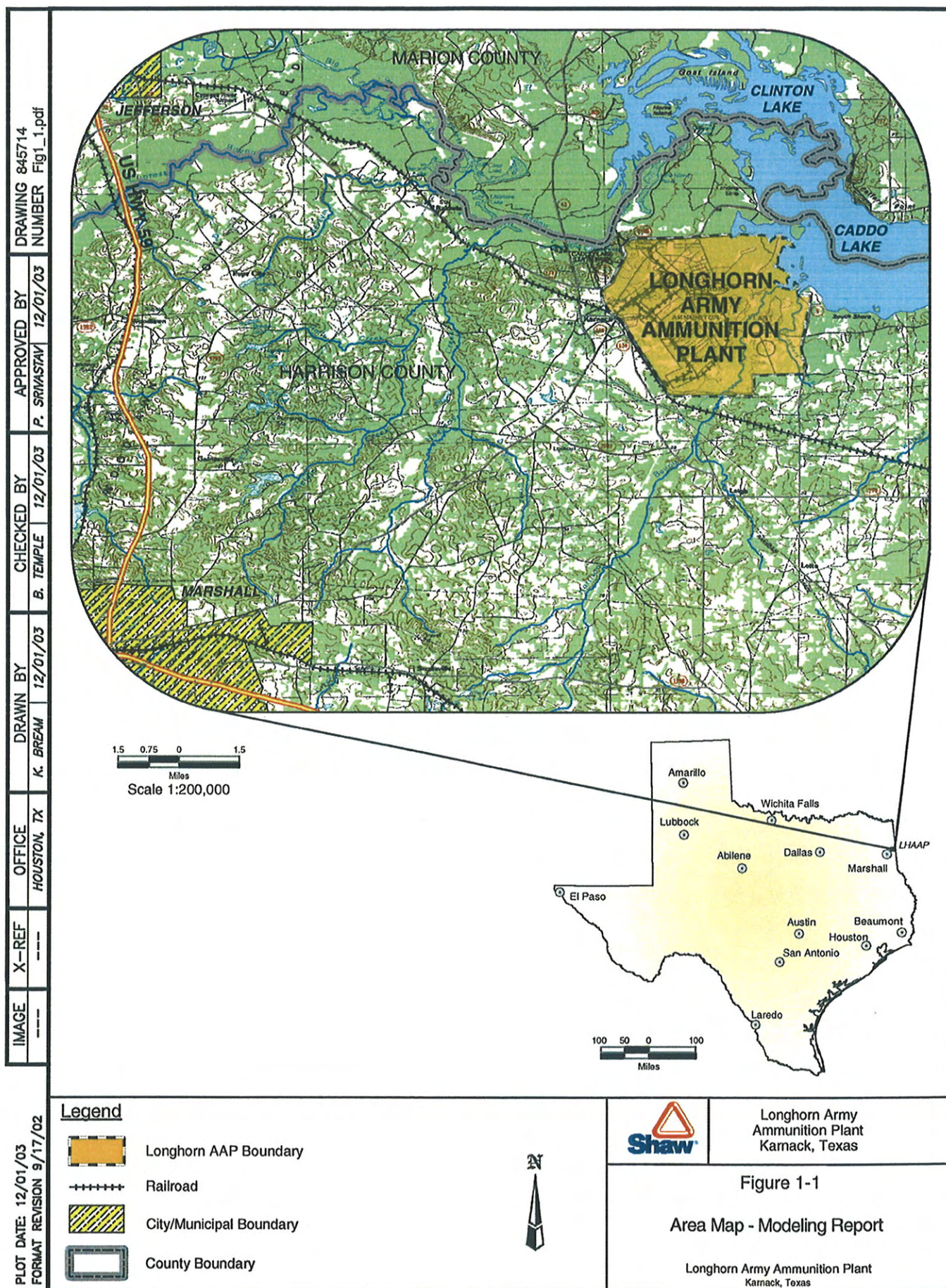
This modeling report was prepared by Shaw Environmental, Inc. (Shaw), for the U.S. Army Corps of Engineers, Tulsa District, under Total Environmental Restoration Contract DACA56-94-D-0020, Task Order 0109, and presents the results of fate and transport modeling of chemicals of concern (COCs) in soil and groundwater, and their potential for discharge to the surface water and sediment of creeks and bayous within Longhorn Army Ammunition Plant (LHAAP) that ultimately flow into Caddo Lake.

LHAAP is an inactive, government-owned, formerly contractor-operated and contractor-maintained industrial facility located in central-east Texas in the northeastern corner of Harrison County (**Figure 1-1**). The installation occupies nearly 8,500 acres between State Highway 43 at Karnack, Texas, and the western shore of Caddo Lake. The nearest cities are Marshall, Texas, approximately 14 miles to the southwest, and Shreveport, Louisiana, approximately 40 miles to the southeast. Caddo Lake, a large freshwater lake along the Texas-Louisiana border, bounds LHAAP to the north and east. The Army transferred approximately 5,032 acres to the U.S. Fish and Wildlife Service on May 5, 2004 for management as The Caddo Lake National Wildlife Refuge, with an additional 742 acres transferred in September 2004.

The soil, groundwater, surface water, and sediment at LHAAP have been contaminated by past industrial operations and waste management practices. Previous studies conducted at LHAAP identified contaminants such as volatile organic compounds, heavy metals, perchlorate, and explosives in on-site media. Several areas of contamination are subject to investigation and cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 United States Code 9604).

Analytical equations and computer models were applied to estimate the transport of COCs through various environmental media to exposure points in the surface water bodies. The COCs were chemicals potentially causing unacceptable risk to human or ecological receptors, or chemicals that exceeded a maximum contaminant level (MCL) or an equivalent standard. The models were used to calculate contaminant concentrations in soil and groundwater that, if present in these media at LHAAP, will result in an acceptable risk to human health or ecological receptors at exposure points in the creeks and bayous. Modeling of fate and transport of COCs was conducted at the following sites: LHAAP-04, -12, -29, -35A, -35B, -35C, -46, -47, -48, -50, and -67. Sites LHAAP-35A, -35B, and -35C are also known as LHAAP-58, -37, and -53, respectively. Both names of these sites are currently in use and, therefore, the sites are referred to as LHAAP-35A(58), -35B(37), and -35C(53) throughout this document.

The purpose of the modeling effort was to identify those sites at LHAAP where COCs in soil or groundwater represent unacceptable human health risk, however, the concentrations of these COCs are not high enough to generate an unacceptable human health or ecological risk in nearby surface water bodies. The results of the modeling effort are intended to be used for selection of risk-based alternatives, which are not necessarily alternatives involving clean up, in the feasibility studies for the sites. For example, land-use controls to prevent exposure to groundwater may be appropriate for a site where COCs in the groundwater pose an unacceptable risk to human receptors but do not cause an unacceptable risk to human or ecological receptors in a nearby creek.



2.0 *Physical Setting*

2.1 *Surface Hydrology*

The surface water at LHAAP drains to the northeast into Caddo Lake, a part of Big Cypress Bayou, via four drainage systems (**Figure 2-1**): Saunders Branch, Harrison Bayou, Central Creek, and Goose Prairie Creek, all of which are intermittent streams. Saunders Branch begins immediately south of the southeast corner of LHAAP. From the southern boundary to Long Point Road, Saunders Branch flows within a confined channel. In the vicinity of Long Point Road, beaver dams inhibit the stream's flow and create extensive wetlands. From Long Point Road to the north perimeter fence, Saunders Branch flows in a less confined channel resulting in a broad stream profile, becoming confined again beyond the northern perimeter fence, until it reaches Caddo Lake.

Harrison Bayou originates more than 4 miles south of the facility. With the extensive drainage basin south of LHAAP, this stream carries much more water than the other streams on the facility. Approximately 1,400 feet from Caddo Lake, Harrison Bayou maintains a distinct sinuous channel that is not obvious during periods of moderate to high flow rates. Harrison Bayou enters Caddo Lake at a blind inlet.

Central Creek originates off the western boundary of LHAAP in two separate segments. Central Creek also remains substantially in its stream channel for the majority of the area within LHAAP. Approximately 3,000 feet from the fence line near Caddo Lake, Central Creek becomes more sinuous.

Originating immediately off the northwest corner of LHAAP, the flow of Goose Prairie Creek is confined within its embankment for the majority of its traverse across LHAAP. Goose Prairie Creek has two separate channels that flow into Caddo Lake. One channel proceeds generally east-west and the other channel flows generally east-west and then north into Goose Prairie Cove.

2.2 *Geology and Hydrogeology*

The subsurface geology at LHAAP consists of a thin veneer of Quaternary alluvium overlying Tertiary age formations of the Wilcox and Midway Groups. Underlying these sediments are Cretaceous age formations of the Navarro and Taylor Groups.

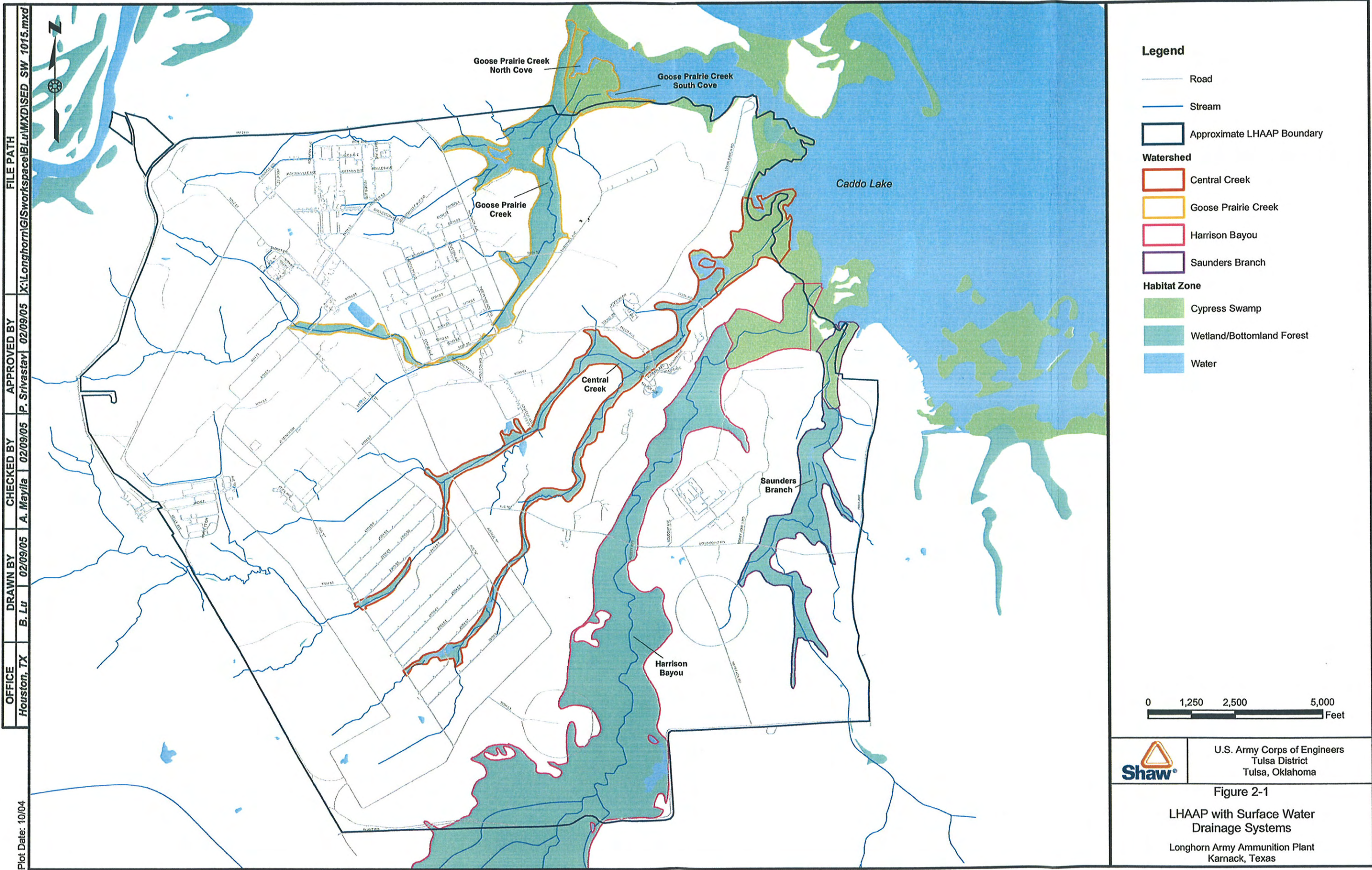
The stratigraphic thickness of the uppermost Wilcox Group ranges from a maximum of 350 feet in the northwest corner of LHAAP to approximately 130 to 140 feet along the east side of the facility near Caddo Lake. The Wilcox Group formation constitutes the majority of the unconsolidated sediments underlying LHAAP. The Wilcox Group consists of interbedded sands,

silts, and clays. These sediments were deposited in a regressive fluvial-deltaic and transgressive marine environment that resulted in considerable stratigraphic heterogeneity over short distances across the site.

The unconsolidated sediments of the Wilcox Group formation typically consist of three sandy, water-bearing zones separated by semiconfining layers of silty clay. The uppermost portion of the Wilcox Group formation at LHAAP consists of medium plastic sandy silts and clays ranging in thickness from approximately 5 to 15 feet. These surficial sediments are underlain by the first or shallow saturated sand zone, which ranges in thickness from 10 to 20 feet. This sand zone consists of silty fine sand containing some silt and clay lenses and is at first dry to moist and then generally becomes saturated at 15 to 20 feet below ground surface (bgs). A 5- to 20-foot-thick medium to highly plastic silt and clay layer underlies the shallow saturated sand zone. An intermediate saturated sand zone, consisting of fine to medium silty sand, is then encountered below the semiconfining layer at 30 to 50 feet bgs. The intermediate saturated sand zone is generally less silty than the shallow saturated sand zone and exhibits higher hydraulic conductivity. A silt to silty clay layer is encountered beneath the intermediate saturated sand zone and ranges in thickness from 5 to 30 feet. Underlying this silt to silty clay layer, a massive homogeneous silty, clayey, fine sand layer is encountered at a depth that continues to the top of the underlying Midway Group formation (approximately 200 to 300 feet bgs).

Groundwater generally occurs under semi-confined to confined conditions. Because of the high degree of stratigraphic heterogeneity, the level of interconnection between the shallow, intermediate, and deep water-bearing zones in the Wilcox Group deposits at LHAAP is highly variable. The depth to groundwater across the facility ranges from 1 to 70 feet bgs, with the typical depth at 12 to 16 feet. The regional groundwater flow direction is generally east-northeast towards Caddo Lake, but varies by site location.

Geologic cross sections are available for some select sites, LHAAP-35A, LHAAP-12, LHAAP-46, and LHAAP-47, and are included in reports by Jacobs Engineering (Jacobs, 2001b; Jacobs, 2002a).



3.0 *Modeling Considerations for Chemicals of Concern at Select LHAAP Sites*

Modeling was conducted for a total of 11 sites including LHAAP-04, -12, -29, -35A(58), -35B(37), -35C(53), -46, -47, -48, -50 and -67 (**Figure 3-1**); sites that are currently in the feasibility study phase. Chemicals of concern at each site were identified in the baseline human health and the screening ecological risk assessments conducted by the Jacobs Engineering Group (Jacobs, 2002d; 2002e) as chemicals that constituted potential unacceptable risk to human or ecological receptors. More recent data from the plant-wide perchlorate investigation identified perchlorate as an additional COC at some of the sites. Chemicals that were of concern for specific media or exceeded an MCL or an equivalent standard were designated as potential COCs for modeling. From this extensive list of chemicals at each site, a smaller number of target COCs were selected for modeling in order to keep the modeling effort focused on addressing primary issues at each site. The proportion of risk contributed by each COC for a specific site was also a factor in the COC selection (Shaw, 2004a). Not all chemicals that exceeded their respective MCL or an equivalent standard at a specific site were modeled. Only those COCs that were predominant contributors to the cancer risk or non-cancer hazard at a site were selected for modeling. Further, if a group of chemicals (e.g., solvents) contributed equally to risk, a subset of COCs was carefully selected for modeling if these COCs could serve as surrogates for the other chemicals of the same group, and had physical or chemical properties that qualified them as appropriate representatives of the remaining COCs. Surrogates were utilized for chemicals with comparatively high adsorption and short half-lives. Available documentation was reviewed including remedial investigation reports for Group 2 and Group 4 sites (Jacobs, 2001b, 2002a), remedial investigation report addendum for Group 4 sites (Jacobs, 2002b), human health and ecological screening risk assessment reports for the Groups 2 and Group 4 sites (Jacobs, 2002d, 2002e), and perchlorate investigation reports (Jacobs, 2001a, Solutions to Environmental Problems, Inc. 2003) in order to compile the list of COCs, their maximum concentrations at each site, and site-specific hydrogeological information. **Table 3-1** summarizes the modeled environmental media, pathways, and rationale for the selection of COCs at each site. Shaw has collected additional analytical and hydrogeological data (Shaw, 2005) and the results of the modeling were compared to the results of the recent data presented in the Data Gaps Investigation report.

Modeling was not conducted for sites where the proximity of a site or plume to a surface water body allowed the use of actual data to make a determination as to whether or not contaminants were being released to the surface water or sediments, or if a site was considered a candidate for remediation in the future based on extremely high concentrations of contaminants (e.g., LHAAP-16, -17, and -18/24). Modeling of COCs was also not conducted for sites where

chemicals present in media did not present unacceptable risk to human or ecological receptors nor had concentrations below MCL or equivalent standards. An exception to this rule were three sites, LHAAP-35A(58), LHAAP-46 and LHAAP-48, where the fate and transport of chemicals was evaluated because of high concentrations of the chemicals in the soil even though the chemicals did not present a human health risk from exposure to the soil.

3.1 *Soil*

Pathways modeled for transport of contaminants from a contaminated soil source included: (a) erosion of soil and transport to surface water and sediment; (b) leaching of contaminants from soil to groundwater; (c) transport and dilution of contaminants by groundwater until discharge to surface water; and (d) transport and dilution by surface water. Perchlorate was the only COC modeled in the soil medium, as a chemical presenting significant human health risk. Erosion of soil and migration of perchlorate to sediment and surface water was calculated at three sites: LHAAP-04, -35C(53), and -47. Leaching of perchlorate from soil to groundwater was modeled at two sites: LHAAP-04 and -47.

Although not posing a human health risk, the migration of bis(2-ethylhexyl)phthalate at LHAAP-35A(58) and LHAAP-46 was modeled because of high concentrations of these chemicals. Erosion of soil and migration of bis(2-ethylhexyl)phthalate to sediment and surface water was calculated at two sites, LHAAP-35A(58) and LHAAP-46. Leaching of bis(2-ethylhexyl)phthalate from soil to groundwater was modeled at LHAAP-35A(58). Erosion of soil and migration of vinyl chloride (VC) and tetrachloroethene (PCE) to sediment and surface water as well as leaching of these chemicals to groundwater, were modeled at LHAAP-48.

3.2 *Groundwater*

Migration of COCs in groundwater from a site to a potential downgradient point of entry (POE) into surface water was estimated using the transport model Analytical Transient One-, Two-, and Three-Dimensional (AT123D) and the Domenico equation. Eleven groundwater COCs were modeled including trichloroethene (TCE), 1,2-dichloroethane (1,2-DCA), VC, 1,1-dichloroethene (1,1-DCE), (PCE), methylene chloride, hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), pentachlorophenol (PCP), 1,1,1-trichloroethane (1,1,1-TCA), 1,1,2-TCA, and perchlorate. Migration of COCs in groundwater to the nearest surface water body was modeled from LHAAP-04, -35A(58), -35B(37), -46, -47, and -50 to Goose Prairie Creek; from LHAAP-12, -29, and -67 to Central Creek; and from LHAAP-35C(53) to both Central Creek and Harrison Bayou. There is no impact to Saunders Branch from the 10 sites modeled for this report. Because LHAAP-48 is located on both sides of the tributary of the Central Creek and the monitoring wells are very close to the tributary, it was assumed conservatively that the contaminants (TCE and perchlorate) have already occurred in the creek, therefore no fate and transport modeling was performed. Only mixing concentrations were calculated.

Metals and dioxins in the groundwater posed unacceptable human health risk at sites LHAAP-35C(53), LHAAP-46, and LHAAP-48. It is possible that the elevated levels of metals and dioxins in the groundwater were due to high turbidity of the samples. The groundwater at sites LHAAP-35C(53) and LHAAP-48 was recently sampled during the Data Gaps Investigation (Shaw, 2005). However, the results were not conclusive and additional sampling is planned. Groundwater at LHAAP-46 may also be resampled in the future. No modeling for these chemicals was conducted due to the evaluation currently underway.

TCA isomers were considered in the groundwater transport modeling only at LHAAP-67. TCA isomers were not selected for modeling at other sites because at two of the sites (LHAAP-47 and 50), the maximum detected concentrations were below the MCL. The proportion of risk contributed by each COC for a specific site was one of the factors in the COC selection (Shaw, 2004a). The risk contributed by TCA at LHAAP-35A was minor (8 µg/L) compared with other contaminants that were modeled (trichloroethene, PCE, 1-1, dichloroethene, RDX, and perchlorate).

Table 3-1
Rationale for Selection of Chemicals of Concern

Site	Medium	Modeled Path	Chemical of Concern	Regulatory Limits ^a (µg/L, unless noted otherwise)	Maximum Concentration at Source (water-µg/L) (soil-µg/kg)	Sample Location	Rationale for Modeling the Contaminant
LHAAP-4	Soil	Surface soil to surface water - Goose Prairie Creek	Perchlorate	4.0 (IAL)	163,000 ^b	04SS06/0-0.5	Elevated concentration of 163,000 µg/kg.
	Groundwater	Surface soil to sediment - Goose Prairie Creek Soil leachate to groundwater Groundwater to surface water - Goose Prairie Creek		25 mg/kg ^f 4.0 (IAL)	--	--	In soil, only 5 feet to water table.
LHAAP-12	Groundwater	Groundwater to surface water - Central Creek	Trichloroethene	5.0 (MCL)	495 ^d	12WW12	Elevated concentration in groundwater higher than MCL.
			Vinyl Chloride	2.0 (MCL)	2.1	12WW02	Elevated concentration in groundwater higher than MCL.
			Perchlorate	4.0 (IAL)	56 ^b	12WW01	Elevated concentration in groundwater higher than IAL.
LHAAP-29	Groundwater	Groundwater to surface water - Central Creek	Trichloroethene	5.0 (MCL)	1,200 ^d	29WW15	Elevated concentration in groundwater higher than MCL.
			1,2-dichloroethane	5.0 (MCL)	14,000 ^d	29WW15	Elevated concentration in groundwater higher than MCL.
			Methylene Chloride	5.0 (MCL)	6,600,000 ^d	29WW16	Elevated concentration in groundwater higher than MCL.
			Perchlorate	4.0 (IAL)	61,400 ^b	29WW15	Elevated concentration in groundwater higher than IAL.
LHAAP-35A (LHAAP-58)	Groundwater	Groundwater to surface water - Goose Prairie Creek	Trichloroethene	5.0 (MCL)	160 ^e	LHSMW05	Elevated concentration in groundwater higher than MCL.
			1,1-dichloroethene	7.0 (MCL)	1,340 ^e	LHSMW07	Elevated concentration in groundwater higher than MCL.
			Tetrachloroethene	5.0 (MCL)	49,010/5,400 ^e	LHSMW05	Elevated concentration in groundwater higher than MCL.
			RDX	26.0 (MSC)	88 ^e	LHSMW03	Elevated concentration in groundwater higher than the MSC.
			Perchlorate	4.0 (IAL)	36.9 ^e	LHSMW01	Elevated concentration in groundwater higher than IAL.
LHAAP-35B (LHAAP-37)	Groundwater	Groundwater to surface water - Goose Prairie Creek	Trichloroethene	5.0 (MCL)	330 ^e	LHSMW59	Concentrations of TCE, 1,1-DCE, and PCE are higher than MCLs
			1,1-dichloroethene	7.0 (MCL)	58 ^e	LHSMW58	and sources are only 125 feet away from Goose Prairie Creek.
			Tetrachloroethene	5.0 (MCL)	34 ^e	LHSMW58	
LHAAP-35C (LHAAP-53)	Soil	Surface soil to sediment - Central Creek or Harrison Bayou	Perchlorate	25 mg/kg ^f	60.9 ^e	35CSB03/0-0.5	Concentration in topsoil is 61 µg/kg.
	Groundwater	Surface soil to surface water - Central Creek or Harrison Bayou Groundwater to surface water - Central Creek or Harrison Bayou	Perchlorate Trichloroethene	4.0 (IAL) 5.0 (MCL)	60.9 ^e 7 ^e	35CSB03/0-0.5 LHSMW67	Concentration in groundwater higher than MCL.
LHAAP-46	Groundwater	Groundwater to surface water - Goose Prairie Creek -Middle	Perchlorate	4.0 (IAL)	30 ^b	46WW04	Elevated concentration in groundwater higher than IAL.
LHAAP-47	Soil	Subsurface soil to sediment - Goose Prairie Creek	Perchlorate	25 mg/kg ^f	180,000 ^e	25C-21/1.5-2.0	Concentration in top soil at 180,000 µg/kg.
	Groundwater	Subsurface soil to surface water - Goose Prairie Creek Soil leachate to groundwater Groundwater to surface water - Goose Prairie Creek	Perchlorate Perchlorate Trichloroethene Tetrachloroethene Pentachlorophenol Vinyl Chloride Perchlorate	4.0 (IAL) 5.0 (MCL) 5.0 (MCL) 1.0 (MCL) 2.0 (MCL) 4.0 (IAL)	190,000 ^e -- 29,410 ^e 168 ^e 7.9 ^e 127 ^e 82,900 ^b	25C-06/4.0-5.0 -- LHSMW43 LHSMW43 LHSMW47 LHSMW56 LHSMW60	Possible leachate from elevated levels in soil less than 5 feet from water table. Elevated concentration in groundwater higher than MCL. Elevated concentration in groundwater higher than MCL. Concentration in groundwater higher than MCL. Elevated concentration in groundwater higher than MCL. Significant contribution by leachate from soil.

Table 3-1
Rationale for Selection of Chemicals of Concern

Site	Medium	Modeled Path	Chemical of Concern	Regulatory Limits ^a (µg/L, unless noted otherwise)	Maximum Concentration at Source (water-µg/L) (soil-µg/kg)	Sample Location	Rationale for Modeling the Contaminant
LHAAP-48	Groundwater	Groundwater to surface water - Central Creek	Trichloroethene	5.0 (MCL)	9 ^e	LHSMW63	Elevated concentration in groundwater higher than MCL.
			Perchlorate	4.0 (IAL)	160 ^e	LHSMW62	Elevated concentration in groundwater higher than IAL.
LHAAP-50	Groundwater	Groundwater to surface water - Goose Prairie Creek	Trichloroethene	5.0 (MCL)	22,000 ^d	50WW02	Elevated concentration in groundwater higher than MCL.
			Tetrachloroethene	5.0 (MCL)	35 ^e	50WW02	Elevated concentration in groundwater higher than MCL.
			1,2-dichloroethane	5.0 (MCL)	98 ^e	50WW02	Elevated concentration in groundwater higher than MCL.
			Vinyl Chloride	2.0 (MCL)	100 ^e	50WW02	Elevated concentration in groundwater higher than MCL.
			Perchlorate	4.0 (IAL)	18,000 ^b	50WW02	Elevated concentration in groundwater higher than IAL.
LHAAP-67	Groundwater	Groundwater to Central Creek	Trichloroethene	5.0 (MCL)	6.3 ^d	67WW01	Elevated concentration in groundwater higher than MCL.
			1,2-dichloroethane	5.0 (MCL)	27 ^f	67WW01	Elevated concentration in groundwater higher than MCL.
			1,1-dichloroethene	7.0 (MCL)	380 ^f	67WW01	Elevated concentration in groundwater higher than MCL.
			1,1,1-trichloroethane	200 (MCL)	1,800 ^f	67WW03	Elevated concentration in groundwater higher than MCL.
			1,1,2-trichloroethane	5.0 (MCL)	33 ^f	67WW01	Elevated concentration in groundwater higher than MCL.

Notes:

-- Data were not collected, or results are non-detect, or below regulatory levels.

^a Value represents the maximum concentration limit (MCL), the TCEQ risk-based medium specific concentration (MSC) for industrial use, or the TCEQ interim action level (IAL) for perchlorate

^b Solutions to Environmental Problems, Inc., 2003, Draft Final Project Report Plant-Wide Perchlorate Investigation, Longhorn Army Ammunition Plant, Karnack Texas, March

^c Sediment protective concentration level for human risk from the Table for Risk Reduction Program Rule, TNRCC, 2002.

^d Jacobs, 2001b, Final Remedial Investigation Report (Volume 1 - 3) for the Group 2 Sites 12, 17, 18/24, 29, and 32, Longhorn Army Ammunition Plant, Karnack, Texas, April

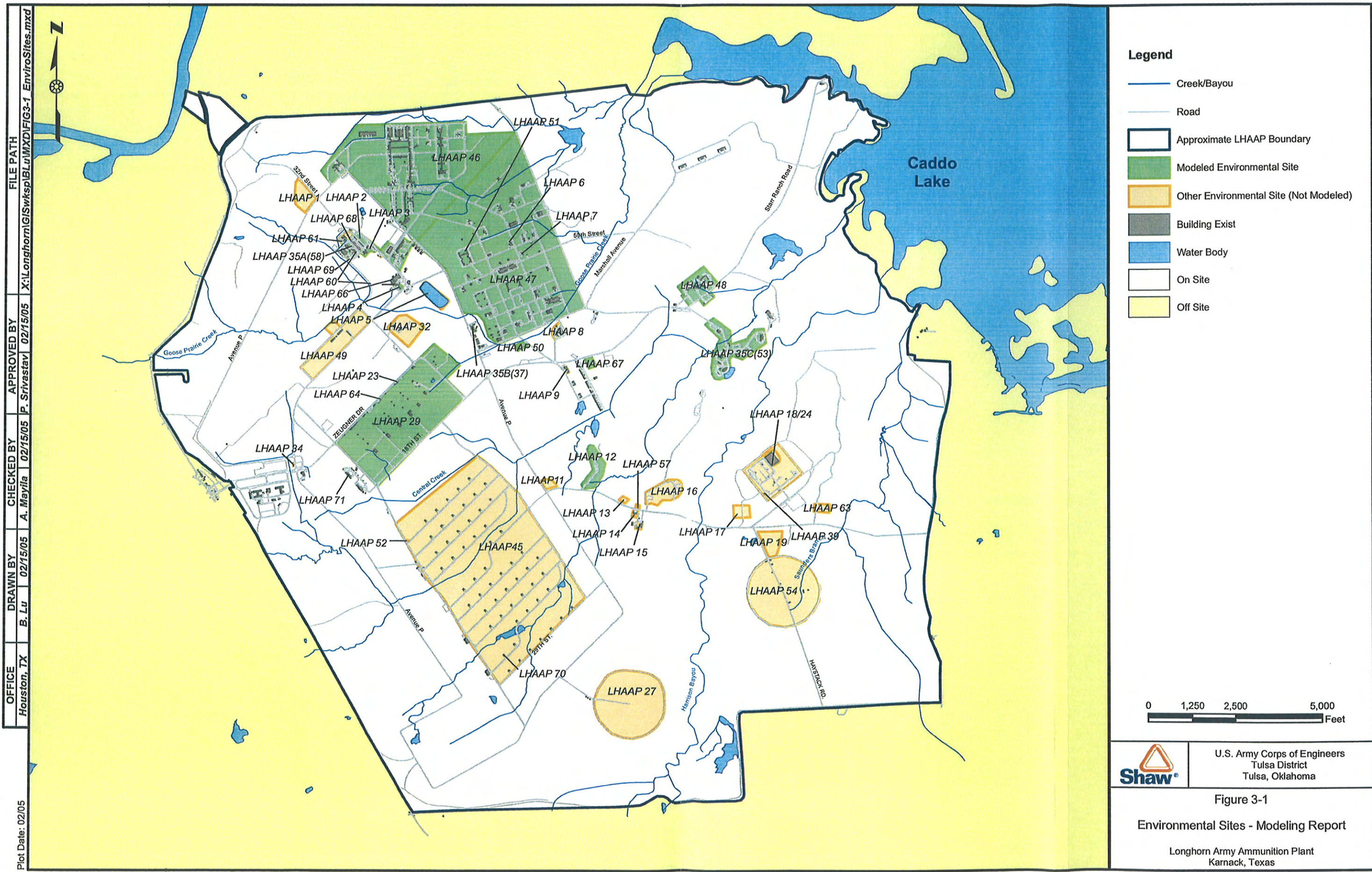
^e Jacobs, 2002a, Final Remedial Investigation Report (Volume 1 & 2) for the Group 4 Sites 35A, 35B, 35C, 46, 47, 48, 50, 50, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas, January

^f Jacobs, 2002b, Final Remedial Investigation Report Addendum for the Group 4 Sites 04, 08, 67, and Hydrocarbon Study, Longhorn Army Ammunition Plant, Karnack, Texas, February

µg/kg micrograms per kilogram

µg/L micrograms per liter

mg/kg milligrams per kilogram



4.0 *Development of Protective Medium-Specific Concentrations for Chemicals of Concern*

Analytical equations and computer models were used to calculate concentrations of COCs during their migration through various environmental media to exposure points in the surface water bodies. Except for perchlorate in the groundwater at LHAAP-29, the historically maximum concentration of a COC detected in the medium of concern at a site was utilized for calculations and modeling, thus presenting the worst-case scenario. At LHAAP-29, perchlorate levels in the groundwater showed a decreasing trend with time (**Table 4-1**); therefore, the most recent high value was used in modeling. Specific media and the models used in this effort depended upon the contaminated source medium and anticipated pathway of contaminant migration (**Table 3-1**).

The modeling effort yielded a dilution factor (DF) for a contaminant between the location of the contaminated source medium and an exposure point in the surface water. The DF was used to derive on-site medium-specific concentrations (MSCs) based on applicable regulatory standards or risk-based remedial goals at the exposure point.

4.1 *Medium-Specific Concentration*

Development of MSCs is in compliance with Texas Commission on Environmental Quality (TCEQ) regulations described in 30TAC§335.160. The MSC values for groundwater at LHAAP sites were developed to be protective of surface water and sediment at locations both on and off LHAAP property. Calculation of soil MSCs was performed in accordance with the procedures described in Texas Risk Reduction Standards (30TAC§335.551-335.569) and associated TCEQ memoranda and updates (Texas Natural Resource Conservation Commission [TNRCC], 1998).

Analytical equations and models were used to develop on-site soil and groundwater MSCs that are protective of human and ecological receptors at exposure points in creeks and bayous. Migration of COCs in groundwater from a site to an exposure point in the surface water was estimated using a transport model, which yielded a chemical-specific DF. The DF was used to multiply the applicable regulatory standard to develop a groundwater MSC. During discussions with regulatory agencies, it was decided that the standard to be met in the surface water of the creeks would be the TCEQ ecological benchmark value, in the absence of which, either the MCL or interim action level (IAL) for perchlorate would be used (minutes of the Longhorn Monthly Manager's Meeting, November 11, 2003). However, because Caddo Lake is a drinking water source for several neighboring communities in Texas and Louisiana, and creeks at LHAAP flow into Caddo Lake, the MCL (or Texas IAL for perchlorate) was used as the criteria for the surface water in the creeks in order to be conservative (**Table 3-1**).

The resulting groundwater MSC was interpreted as the groundwater concentration at a compliance point on site or at an off-site downgradient location that will be protective of the surface water farther downgradient.

Groundwater MSCs developed for COC transport to sediments were based on TCEQ's protective concentration limits for sediments (**Table 3-1**). Groundwater and soil MSCs were developed to be protective of the drinking water source at Caddo Lake, and human and ecological receptors exposed directly to the surface water and sediment. The MSCs are specific to the site, transport pathway, receptor surface water body, and COC.

4.2 *Analytical Models*

Four analytical models were utilized for calculation of protective levels in various media. Contaminant migration from (1) topsoil to sediments, (2) surface soil to surface water, (3) subsurface soil to groundwater, and (4) groundwater to the surface water were calculated using the appropriate analytical equation and or model as described in the Technical Memorandum (Shaw, 2004a) and summarized in the following sections.

Data Collection and Review

Soil and groundwater data from existing remedial investigation reports (Jacobs), and U.S. Department of Agriculture (USDA) and U.S. Environmental Protection Agency (USEPA) maps were reviewed and compiled for the modeling effort. The data collection focused on information useful for input to the models. The following were reviewed in detail:

- Historical and current water level information
- Contaminant concentration data (spatial and temporal distributions)
- Slug test data (permeability and hydraulic conductivity)
- Precipitation rates
- Stream elevations from surveys or accurate detailed maps
- Stream flow data
- Isoerodent maps of the United States of America
- Soil type and composition
- Soil bulk densities
- Soil porosities
- Geologic cross sections
- Potentiometric surface maps
- Organic fraction of soil

The data deemed to be most important to the model, site-specific input parameters, and conservative assumptions were used as model input for each site. When site-specific data were not available, conservative literature values were used.

Analytical methods used to establish the initial contaminant concentrations were those analytical methods listed in the approved Final Work Plans for RI/FS at LHAAP prepared by Jacobs Engineering Group, Inc. and Solutions to Environmental Problems, Inc., as follows:

- VOCs EPA Method 8260A
- SVOCs EPA Method 8270
- Metals (except Hg) EPA Method 6010A
- Hg EPA Method 7471A
- Explosives EPA Method 8330
- Pesticides/PCBs EPA Method 8080A
- Dioxins/Furans EPA Method 8290
- Perchlorate EPA Method 314.0

4.2.1 Surface Soil Concentrations Protective of Sediment and Surface Water

Contaminants released on the land surface are retained between the pore spaces of topsoil, adsorbed on soil particles, or migrated into subsurface soil. Contaminated soil particles are transported by storm-generated runoff to nearby streams or depressions. The following sections describe the calculations used to develop surface soil concentrations protective of sediment and surface water in streams.

4.2.1.1 Calculation for MSC-Soil-Sediment (^{Sed}Soil MSC)

A screening calculation was performed to evaluate whether storm water from sites LHAAP-04, -35A(58), -35C(53), -46, -47 and -48 has the potential to impact nearby receiving water bodies. Soil loss was evaluated at each site using the Revised Universal Soil Loss Equation (RUSLE) before the soil concentration protective of sediment could be calculated.

Soil Loss Calculation

The RUSLE (Version 1.06) was developed jointly by the Agriculture Research Service of the USDA and the Natural Resources Conservation Service in cooperation with Purdue University, the University of Minnesota, and the University of Tennessee (Toy and Foster, 1998). RUSLE is empirical and is based on statistical relationships that support its universal applicability.

The RUSLE is in the form:

$$A = R \times K \times L \times S \times C \times P \quad \text{Equation 4-1}$$

where:

- A = estimated average annual soil loss (kg/acre [ac] per year)
- R = rainfall-runoff erosivity factor (feet-ton-inches per ac per hour per year)
- K = soil-erodability factor (ton/ac per unit of R)

- L = slope length factor (unitless)
- S = slope steepness factor (unitless)
- C = cover management factor (unitless)
- P = support practice factor (unitless)

The RUSLE was used to facilitate the input of the parameters and calculations. The input parameters were all dependent on the actual location of the site being evaluated. The location factor implicitly describes rainfall, land use, surface coverage, soil type, and other factors for the specific location. Since LHAAP is close to Shreveport, Louisiana (**Figure 1-1**) several of the parameters established for Shreveport were utilized in the calculations. **Table 4-2** presents a summary of site-specific input parameters and results for calculations of soil concentrations protective of the sediment.

Rainfall-Runoff Erosivity Factor (R). When factors other than rainfall are held constant, soil losses from cultivated land are directly proportional to a rainstorm parameter:

Total storm energy (E) multiplied by the maximum 30 minute intensity (I). During the current evaluations, R was obtained using the following: **Equation 4-2**

- Isoerodent maps covering the entire United States with R contours available from USDA and USEPA were utilized. An R value for LHAAP of 400 was obtained from **Figure 4-1**, a map showing a portion of the eastern United States (USDA, 1996). This is a conservative value since the LHAAP land is uncultivated.
- The RUSLE software was utilized. The topographic slope of each affected area (contaminant site) was assumed and the slope from the site being evaluated to the nearby creek (total area) was estimated. The overall R value of 400 was given in the template provided by the RUSLE program. **Table 4-3** shows the annual precipitation of 43.8 inches with monthly distributions of rainfall and temperature for the city of Shreveport, which is the nearest location to LHAAP. Hourly EI distribution is also shown in **Table 4-3**. The site specific R factor was estimated for each site.

Soil Erodability (K). The K factor is the ease with which soil is detached by splash during rainfall or by surface flow, or by a combination of both. It is a function of the composition of the soil type, percentage of organic matter, soil structure and grain size, and soil permeability. The K factor is calculated and included on a soil loss and sediment yield computation worksheet for each site. The calculated K factor ranged from 0.12 to 0.192 ton/ac-per unit of R for the sites where soil loss calculations were conducted (**Table 4-2**).

Topographic Factor, including L and S (LS). The value of LS increases as hillslope length and steepness increase.

- Slope length factor (L). Erosion increases as slope length increases. Slope length is defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins, or (2) runoff becomes concentrated in a defined channel.
- Slope steepness factor (S). Slope steepness plays an important role in soil erosion. There are several equations for slopes longer than 15 feet in length and slopes shorter than 15 feet. Slope steepness greater than 9 percent is calculated differently from those slope steepness of less than 9 percent. The length of the slope of the affected and total areas was assumed for each site.

LS values for the sites modeled are shown in **Table 4-2**.

Cover Management Factor (C). The C factor is the ratio of soil loss with specific cropping and management practices to the corresponding loss with up-slope and down-slope tillage and continuously fallow conditions. This factor includes the effects of cover, crop sequence, productivity level, length of growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms. In the RUSLE program, the annual average value was used. The following factors and parameters were assumed because site-specific data were not available:

- Plant : southern grasses
- Annual site production potential of plant: 2 pounds per acre (lb/ac) (affected area) and 50 lb/ac (total area)
- Effective root mass in top 4 inches: 11 lb/ac (affected area) and 280 lb/ac (total area)
- Percent canopy cover: 5 percent and 50 percent (affected and total areas, respectively)
- Roughness for the field condition: 0.8 inches (corresponding to short grass)
- Average fall height: 0.1 foot
- Number of years for soil consolidation: 7 years
- Number of years since last mechanical disturbances: 1 year
- Total percentage of ground covered by rock and residue: variable for each site (affected and total areas, respectively)

The C values were then calculated and are included on the RUSLE calculation results output for each site and in **Table 4-2**.

Support Practice Factor (P). The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing, on soil loss at a particular site. The value of P decreases with the practice of these

factors because they reduce runoff volume and velocity and encourage the deposition of sediment on the slope. As in the case of the C factor, many of the input parameters for the P factor were unknown or not available when the calculations were performed. Therefore, the following inputs were assumed:

- Ridge height: high ridges 4 to 6 inches
- Furrow grade: 0.05 percent
- Overall slope gradient: from 0.1 to 2.22
- Soil type and composition: similar to the K factor above

The P factors for the affected and total area, and the subsequent resultant soil losses were calculated using the RUSLE program and are included on the RUSLE calculation results output for each site and in **Table 4-2**.

In the process of moving towards the watershed outlet, soil will be trapped by vegetation and plant residue or will be deposited in low lying areas, local scour, rills, and channels. Other factors inhibiting the eroded material's delivery to the watershed outlet include climate, soil particle size and texture, size and proximity of the upland erosion source, the ratio of rill versus sheet erosion, total watershed area, watershed length and relief, and drainage density. Therefore, not all of the soil loss calculated by the above approach will reach the watershed outlet. The sediment yield or load at the outlet was estimated using a sediment delivery ratio (SDR) from 0 to 1 to account for the above-mentioned deduction factors. RUSLE is designed to calculate the SDR by assigning different values for permanent barriers (strips or concaves) and terraces or sediment basins that include the land slope, soil type and texture etc. Because many of the site specific data are not available, assumptions were made, similar to the assumptions described in the previous sections. The SDR value and the annual sediment yields were estimated using RUSLE and are included on the RUSLE calculation results output for each site and are shown in **Table 4-2**.

Calculate^{Sed}Soil MSC

The soil concentration protective of sediment, ^{Sed}Soil MSC (or C_{AP}), was calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT}) - (SL_{OA} \times C_{OA})}{SL_{AP}} \quad (mg/kg) \quad \text{Equation 4-3}$$

where:

C_{AP} = the ^{Sed}Soil MSC in milligrams per kilogram (mg/kg) for the surface water runoff pathway from the affected area.

- SL_{TOT} = total sediment load estimated for the entire contributing watershed (kg/ac per year).
- C_{TOT} = published regulatory sediment MSC (mg/kg) for the COC.
- SL_{OA} = sediment load (kilogram per year [kg/yr]) estimated for other areas of the watershed.
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds because there is no Texas-specific median background soil concentrations; thus $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area.
- SL_{AP} = sediment load from the affected property (kg/yr).

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT})}{SL_{AP}} = {}^{Sed}Soil\ MSC \quad \text{Equation 4-4}$$

The ${}^{Sed}Soil\ MSC$ value is compared with the affected property surface soil concentration to determine if the erodable soil concentrations exceed the ${}^{Sed}Soil\ MSC$. Calculations for soil concentrations protective of sediment were conducted for three sites (LHAAP-04, -35C[53], and -47).

4.2.1.2 Calculation for MSC-Soil-Surface Water (${}^{SW}Soil\ MSC$)

Screening for the erodable soil to surface water pathway was conducted using conservative screening equations that account for some affected property and watershed characteristics. The sediment load to the surface water body calculated using RUSLE and delivery ratio approaches can be used to estimate the load on surface water during average flow conditions and to estimate the greatest potential effect on the water body. This assumption is necessary to account for the maximum release from the affected property and is supported by the theory that sediment from eroded soil is transported toward the outlet by intensive and heavy rainstorm but not necessarily flushed into the surface water body by the same storm; therefore, the flow in the stream does not necessarily correspond to this storm (USEPA, 1985). In the current study, it was conservatively assumed that “7Q2” conditions in the creeks (flow in seven consecutive days occurs once every 2 years; i.e., an exceedance probability of 0.5) prevail and, therefore, pose a greater effect on the creek after mixing and dilution. However, because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2.

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation 4-5}$$

where:

C_{AP} = concentration of COC in runoff from the affected property (milligrams per liter [mg/L])

Q_D = flow downstream of the affected property watershed (cubic feet per second [ft³/sec]), using 7Q2 flow

C_D = concentration of COC downstream of the affected property (mg/L)

Q_{AP} = runoff from the affected property (ft³/sec)

Q_{OA} = runoff from other areas of the affected property watershed (ft³/sec)

C_{OA} = concentration of COC in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes are based on the Schueler Method (Schueler, 1987).

First, the runoff coefficient for each land use type can be derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U) \quad \text{Equation 4-6}$$

where:

I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates are then calculated using the following equation:

$$Q = P \times P_J \times R_{VU} \times A_U \text{ (ft}^3\text{/sec)} \quad \text{Equation 4-7}$$

where:

P = precipitation rate (inches/year)

P_J = ratio of storms producing runoff (unitless) with a default value of 0.9

R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})

A_U = area of land use type U (acres)

At each site the area of affected property and the percent imperviousness (I_U) for the affected property and the other area (OA) of the affected property watershed are estimated based on site maps.

Q_{AP} is then calculated. Q_D is obtained based on 7Q2 flow charts for each site. Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and, therefore, the other areas of the affected property watershed are omitted.

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} \quad \text{Equation 4-8}$$

When the COC concentration downstream of the affected property (C_D) is set equal to a regulatory standard, the resulting C_{AP} represents the COC concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} \quad \text{Equation 4-9}$$

The concentration of COC in the solute, $Conc_{source}$ (mg/L), can be derived from the measured soil concentration, $Conc_{soil}$ in mg/kg (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation 4-10}$$

where:

- ρ_b = bulk density of soil
- k_d = distribution coefficient
- ϕ_w = water-filled porosity
- ϕ_a = air-filled porosity
- H_c = Henry's law coefficient

Using the equation used above, COC concentration in soil (C_{soil}) can be back-calculated by setting COC concentration in due solute ($Conc_{source}$) equal to C_{AP} :

$$C_{soil} = \frac{[\phi_w + H_c \phi_a] C_{AP}}{\rho_b} = {}^{SW}Soil\ MSC \quad \text{Equation 4-11}$$

This value C_{soil} ($= {}^{SW}Soil\ MSC$), is the soil concentration protective of surface water. Calculations for soil concentrations protective of surface water were conducted for six sites, LHAAP-04, -35A(58), -35C(53), -46, -47, and -48.

4.2.2 Subsurface Soil Concentrations Protective of Groundwater

Contaminants in the soil, especially in the vadose zone, migrate mainly to the groundwater. It is necessary to calculate the DF of contaminant concentration in groundwater after mixing so that the MSC for soil that is protective of groundwater (*GWP*) derived based on the DF.

$$GWP = \frac{GW}{DF} \quad \text{Equation 4-12}$$

where:

GW is the regulatory standard for groundwater (MCL or IAL) for the COC, when available.

The dimensional integrity of this equation is maintained by assuming the density of water is 1 kilogram per liter (kg/L).

Vadose Zone Leaching and Saturated Zone Mixing

For modeling of soil leaching to groundwater, and groundwater transport between shallow and intermediate zones, the DF was derived by calculating the mixing concentration in groundwater ($Conc_{mix}$) contributed by the contaminant source in the soil. The calculation was performed using USEPA's leaching model, Vadose Zone Leaching and Saturated Zone Mixing (VLEACHSM), a modification of VLEACH (ASTM, 1999). VLEACHSM was utilized for modeling soil leaching to groundwater at three sites: LHAAP-04, -35A(58), and -47.

The VLEACHSM model is a one-dimensional finite-difference vadose zone leaching model. The model estimates impact to groundwater due to the mobilization and migration of contaminants in the vadose zone, and subsequently estimates mixing in the saturated zone. The model simulates the transport processes including liquid-phase advection, liquid- and vapor-phase dispersion, sorption, and decay of the contaminant. The model input parameters for the hydrogeologic and chemical properties are assumed to be uniform and homogeneous throughout the simulation.

The initial contaminant concentration distribution in the vertical polygon (soil column) from the land surface to the water table is used as input to the model.

Other input parameters include duration of the source release, chemical distribution coefficient (partition coefficient), Henry's law coefficient, solubility of contaminant, free air diffusion coefficient, longitudinal dispersion coefficient, bulk density of soil, water-filled porosity, air-filled porosity, decay rate, groundwater recharge rate, Darcy velocity of groundwater, and background concentration in groundwater. Literature values were used when site-specific data were not available. **Table 4-4** presents input parameters for VLEACHSM.

Two types of results are provided by VLEACHSM simulation: the contaminant profile in soil varying with time and the mixing concentration in groundwater varying with time. The time-varying COC concentration in the leachate is described as $Conc_{source}$ in mg/L and is calculated by the equation (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation 4-13}$$

where:

- $Conc_{soil}$ = Chemical concentration in soil (mg/kg)
- ρ_b = Bulk density of soil (grams per cubic centimeter [g/cm³])
- k_d = distribution coefficient [cubic centimeters per gram (cm³/g)]
- ϕ_w = Water-filled porosity (unitless)
- ϕ_a = Air-filled porosity (unitless)
- H_c = Henry's law coefficient (unitless)

The time-varying concentration after mixing with groundwater is described as $Conc_{mix}$, in mg/L (ppm). Then DF (unitless) is calculated as:

$$DF = \frac{Conc_{source}}{Conc_{mix}} \quad \text{Equation 4-14}$$

The VLEACHSM model employs single values for each input parameter and, therefore, produces single values of $Conc_{source}$ and $Conc_{mix}$ at each time interval. The input values can be the maximum, minimum, mean, or any other descriptor of the concentration data. A modeled concentration at a downgradient receptor location based on a maximum at the source site would approximate an upper bound for the contribution of the source to the receptor. Similarly, the minimum and mean source concentrations would estimate the lower bound and most probable contributions.

4.2.3 Groundwater Concentrations Protective of Surface Water

The area of discharge of a groundwater contaminant plume into a nearby stream is defined as the area (or interface) of the portion of the plume containing chemical concentrations above values protective of human and ecological receptors. This approach provides a calculated MSC for groundwater-to-surface-water pathway (MSC-GW-SW) or ^{SW}GW MSC that is protective of surface water by the groundwater discharge pathway. The method of calculating the mixing concentration accounts for the dilution of contaminants in the stream before they are discharged into another stream or lake.

The analytical computer model AT123D or the Domenico equation was used to calculate the chemical concentration and the DF at the interface where groundwater enters the surface water body.

AT123D

In order to calculate the maximum concentrations of the contaminants in groundwater and the time of transportation just before they are discharged to the surface water body, the computer model AT123D was utilized. AT123D is the acronym for “Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System” (ASTM, 1999). AT123D was developed by Professor G.T. Yeh of Pennsylvania State University for the Oak Ridge National Laboratory in Oak Ridge, Tennessee, and is a public domain model recognized by the USEPA (Yeh, 1987). The model is included in the USEPA publications, *Ground-Water Modeling Compendium* (USEPA, 1994) and *Selection Criteria for Mathematical Models Used in Exposure Assessments: Ground-Water Models* (USEPA, 1988).

AT123D is an analytical groundwater transport model that computes the spatial-temporal concentration distribution of chemicals in an aquifer system and predicts the transient spread of a contaminant plume through a groundwater aquifer. The aquifer is assumed to be homogeneous and isotropic. The fate and transport processes account for advection, dispersion, adsorption, and chemical decay/degradation. AT123D can model two kinds of source releases; an instantaneous and a continuous release with either a constant source loading, or time-varying loading. AT123D can model three types of waste (radioactive, chemical, and heat), four types of source configurations (a point source; a line source parallel to x-, y-, or z-axis; an area source perpendicular to the z-axis; and a volume source), and four variations of the aquifer dimensions (finite depth and finite width, finite depth and infinite width, infinite depth and finite width, and infinite depth and infinite width).

The input required for AT123D includes source size (length, width, depth), source concentration or release load, aquifer size, hydrogeologic parameters (hydraulic conductivity, porosity, hydraulic gradient), longitudinal, lateral, and vertical dispersivities, decay rate of chemicals, time steps, and downgradient points of evaluation. AT123D was utilized at nine sites (LHAAP-04, -29, -35A[58], -35B[37], -35C[53], -46, -47, -50, and -67) to model the groundwater fate and transport.

Domenico Equation

The DF of the COCs at a point of interest downgradient of the source at LHAAP-12 was obtained using the Domenico equation (Domenico and Schwartz, 1998). The model AT123D was not utilized for LHAAP-12 because the results from Domenico equations were considered adequate, considering the low concentrations of COCs at the site. The Domenico equation is an analytical model expressed as follows:

$$DF = \frac{C_{si}}{C_{(x)i}} = \left\{ \exp \left[\frac{x}{2\alpha_x} \left(1 - \sqrt{1 + \frac{4\lambda_i \alpha_x R_i}{v}} \right) \right] \left(\operatorname{erf} \left[\frac{S_w}{4\sqrt{\alpha_y x}} \right] \right) \left(\operatorname{erf} \left[\frac{S_d}{2\sqrt{\alpha_z x}} \right] \right) \right\}^{-1} \quad \text{Equation 4-15}$$

The notations used in this equation are conceptually shown in **Figure 4-2** and also explained below:

DF = dilution factor

C_{si} = concentration of chemical i in source zone (micrograms per liter [$\mu\text{g/L}$])

$C_{(x)i}$ = concentration of chemical i in groundwater at distance x downgradient of source ($\mu\text{g/L}$)

S_w = source width perpendicular to groundwater flow (feet)

S_d = source thickness (i.e., the thickness of the affected groundwater within the permeable zone) (feet). Since the thickness of the contaminated plume is unknown, the average thickness of the water bearing zone is used. The thickness of the shallow permeable zone at LHAAP 12 is in the range of 5 to 20 feet, the average thickness of the permeable water bearing zone (sand) = 12.5 feet.

S_d is a site specific variable. However, it can be determined by adding the depth caused by advection and the depth caused by vertical dispersion:

$$S_d = h_{adv} + h_{disp} \quad \text{Equation 4-16}$$

Where h_{adv} is the advective component of the plume depth (feet):

$$h_{adv} = B \{ 1 - \exp [(-I \times L) / (B \times D_v)] \} \quad \text{Equation 4-17}$$

where B is the aquifer thickness (feet), I is the infiltration rate (feet/year), and L is the source length parallel to groundwater flow (feet).

h_{disp} is the dispersive component of the plume depth:

$$h_{disp} = (2 \times \alpha_z \times L)^{1/2} \quad \text{Equation 4-18}$$

If the calculated S_d exceeds the thickness of the aquifer, then $S_d = B$. In this evaluation the thickness of the groundwater plume is unknown; therefore $S_d = B$.

Dv = groundwater Darcy velocity in feet per year (ft/yr) ($= K \times i$). K is the hydraulic conductivity and i is the hydraulic gradient

v = groundwater seepage velocity in ft/yr ($= Dv/n$), where n is the effective porosity, assumed as 0.25

x = distance downgradient from source to the receiving water body (feet)

foc = fraction of organic carbon content

αx = longitudinal groundwater dispersivity (feet)

αy = transverse groundwater dispersivity (feet)

αz = vertical groundwater dispersivity (feet)

erf = error function value, $erf\chi = \frac{2}{\sqrt{\pi}} \int_0^{\chi} e^{-t^2} dt$, which is available in tables

λ_i = first-order degradation rate for chemical i (day⁻¹)

$$\lambda_i = \frac{\ln 2}{(t_{1/2})_i}$$

where $(t_{1/2})_i$ is the half-life of chemical i

Because no site-specific degradation rate was tested, conservative literature half-life values were used (Howard et al., 1991). The use of degradation rates was justified as follows: two practical evidences suggest that there is some degradation at the sites. During the September 2004 data gap sampling event, geochemistry data were collected from LHAAP-58 (35A). The dissolved oxygen data in most of the monitoring wells showed values less than 1.0 mg/L. The highest was detected at 11.12 mg/L at well 35AWW01, but dropped to only 0.99 mg/L after less than 2 hours during the test. Redox values ranged greatly from -129 to 354. Second, cis-1,2-DCE and vinyl chloride were detected at some sites. These are daughter products of PCE and TCE which proves in itself that dechlorination occurred. On the other hand, recent study at LHAAP-16 shows that sulfate levels are elevated and there is no carbon to sustain significant reductive dechlorination under existing conditions. A study conducted by Geosyntec showed that even when TCE degradation was stimulated in the presence of lactate, vinyl chloride did not degrade, as indicated by a lack of ethene detection. VC degradation potentially may occur only when most of TCE and cis-1,2-DCE have dechlorinated, because the thermodynamics of reductive chlorination favors the higher chlorinated compounds. These conflicting phenomena demonstrate that not only is the geologic condition highly heterogeneous at LHAAP but the

geochemistry is also highly heterogeneous. As such, the reductive dechlorination assumption used in the report may be valid for some sites and not valid for others. Based on current available data and before full scale site investigation is performed, the reductive dechlorination assumption will be conservatively utilized. It is the intention of the Army to present the results of the current transport calculations for PCE, TCE, cis-1,2-DCE and VC at the sites involved (LHAAP-12,- 29, -35A, -35B, -35C, -47, -48, -50 and -67) until such a time that additional data are available to validate the presence or absence of degradation on a site-specific basis.

The retardation factor for chemical i (R_i , dimensionless) is given by the equation:

$$R_i = [1 + (K_d \rho_b / n)] \quad \text{Equation 4-19}$$

where:

K_d = distribution coefficient for the chemical between groundwater and soil (cm³/g)

ρ_b = dry soil bulk density in g/cm³. $K_d = K_{oc} \times f_{oc}$ where K_{oc} is the carbon-water sorption coefficient (cm³/g)

n = porosity

The calculations of the DF for each of the COCs were performed with a spreadsheet and the corresponding concentrations at the interface of groundwater and surface water were obtained.

The Domenico equation used here is under steady state condition. Since it is an analytical model and a non-exact solution which assumes homogeneous, isotropic, it does not require the stringent boundary conditions required by other numerical transport models. The source plume has to be defined in terms of its horizontal and vertical dimensions. The spreading of the plume in the vertical direction is limited by the aquifer's thickness. When the thickness of the source plume is less than the aquifer thickness, it would spread horizontally and vertically downwards until it reaches the entire thickness at which the vertical dispersivity is no longer active and the error function term with α_z in Equation 4-15 becomes unity. The horizontal distance at which the plume touches the bottom can be calculated (Domenico and Schwartz, 1998). There exists obvious limitations to using the Domenico equation. Since each hydrogeologic property is represented by a single value, it can only yield reasonable results in a homogeneous setting. The assumption that the subsurface at the various sites is homogeneous is not realistic. Due to the current conservative assumptions, the conclusions reached are reasonable.

Dilution Factor

Once the COC concentration at the interface of groundwater and surface water was calculated, it was multiplied by the DF (a value greater than one, as defined below) to obtain the mixing concentration $Conc_{mix}$ in the immediate proximity of the groundwater outflow and surface water body. The DF in the surface water body was calculated using the following equation:

$$DF = \frac{Q_{GW}}{Q_{CC} + Q_{GW}} \quad \text{Equation 4-20}$$

where Q_{CC} and Q_{GW} are the flow rates in the surface water body and in groundwater, respectively.

$$Q_{GW} = U_{gw} \times \delta_p \times L_m \quad \text{Equation 4-21}$$

where:

$$\begin{aligned} U_{gw} &= \text{the approaching groundwater velocity (ft/yr)} \\ \delta_p &= \text{the thickness of the plume approaching the surface water body (feet)} \\ L_m &= \text{the width of the plume approaching surface water body (feet)} \end{aligned}$$

Calculation of the surface water flow rate Q_{CC} was based on the 7Q2 stream flow analysis. According to TCEQ (2003), the 10th percentile flow has to be used when stream flow record is less than five years.

The mixing concentration $Conc_{mix}$ and the concentration at the source $Conc_{source}$ ($=C_{si}$) was then used to calculate the overall DF from the source:

$$DF = \frac{Conc_{source}}{Conc_{mix}} \quad \text{Equation 4-22}$$

DF was then used to calculate groundwater concentration protective of surface water MSC-GW-SW ($^{SW}GW MSC$) according to the equation:

$$^{SW}GW MSC = \frac{MSC - SW}{DF} \quad \text{Equation 4-23}$$

where:

$$^{SW}GW MSC = \text{MSC for groundwater at the source area that is protective of human or ecological receptors in surface water at a downgradient location (}\mu\text{g/L)}$$

MSC-SW = Regulatory standard for surface water protective of human or environmental receptors, as appropriate, at the downgradient location, ($\mu\text{g/L}$).

Table 4-1
Perchlorate Analytical Data
LHAAP-29 Selected Shallow Monitoring Wells

Well Number	May-00	Sept/Oct 2000	Jan-01	Mar-02	Sep-02
29WW08				ND	ND
29WW13		30	ND	ND	ND
29WW14		ND		ND	ND
29WW16	35.8	ND	ND	ND	ND
29WW21				ND	ND
Well Number	May-00	Sept/Oct 2000	Jan-01	Mar-02	Sep-02
29WW15		88,000	47,000	61,400	46,400
29WW05		130	130	77.1	65.7
29WW17		130	ND	ND	ND
29WW18		ND		84.7	ND
29WW20		8	ND	ND	ND

Notes and Abbreviations:

Blank cell - not sampled

ND non-detect

ug/L micrograms per Liter

Table 4-2
Input Parameters and Results for Soil Concentrations Protective of
Sediment and Surface Water Calculations

Parameter/Units	Site No.	LHAAP-04	LHAAP-35C	LHAAP-47
Distance to nearest stream (feet)		722	300	192
Topographic slope (%)		0.1	0.4	2.22
Topsoil (%)		29% - silt 70% - clay 1% - organic matter	29% - silt 70% - clay 1% - organic matter	39% - silt and very fine sand 60% - clay 1% - organic matter
Soil erodibility (K) (tons/acre per unit of R)				
Affected area		0.19	0.14	0.12
Total area		0.192	0.19	0.12
Length (L) and Steepness (S) Factors				
Affected area		0.04	0.08	0.37
Total area		0.14	0.08	0.43
Cover Management Factor (C)				
Affected area		0.17	0.12	0.14
Total area		0.119	0.14	0.18
Overall Slope Gradient (%)				
Affected area		0.1	0.1	2.22
Total area		0.69	0.69	2.22
Support Practice factor (P)				
Affected area		0.82	0.82	0.58
Total area		0.98	0.98	0.58
Soil Loss - A (tons/acre-year)				
Affected area		0.44	0.4	1.4
Total area		1.2	0.82	2.2
Annual sediment yield (tons/acre-year)				
Affected area		0.42	0.4	0.73
Total area		1.2	0.82	1.1
Sediment Delivery Ratio (SDR)				
Affected area		0.79	0.74	0.3
Total area		0.92	0.92	0.3

Notes and Abbreviations:

% percent

mg/kg milligrams per kilogram

Table 4-3
Rainfall/Runoff Erosivity (R Factor)
Shreveport, Louisiana

City code: 18003	City: Shreveport	State: Louisiana	
Total P: 43.8 "	El curve #: 96	Freeze-Free days/year: 272	
Elevation (ft): 252	10 year El: 180	R factor: 400	
Mean P (inches)	Tave (deg. F)	%El	%El
4.02	47.8	0	54
3.46	51.7	2	58
3.77	58.15	4	62
4.71	67.05	6	66
4.7	73.7	9	70
3.54	81.2	12	74
3.56	83.45	17	78
2.52	84.15	23	82
3.29	78.75	30	86
2.63	68.45	37	90
3.77	56.25	43	94
3.87	49.8	49	97

Notes and Abbreviations:

ft feet
F Fahrenheit
% percent
P precipitation

Table 4-4
Input Parameters for Modeling Soil Concentrations
Protective of Groundwater using VLEACHSM

Parameter/Units	Site No.	LHAAP-4	LHAAP-47
Distance to nearest stream (ft)		722	312 ^a
Depth to groundwater (ft)		5	6
Source Area in soil (ft x ft)		5 x 5	50 x 50
Hydraulic conductivity (cm/sec)		6.36×10^{-4}	7.49×10^{-4}
Hydraulic gradient		0.0072	0.00397
Longitudinal dispersivity(ft)		0.118	31.2
Vertical dispersivity (ft)		0.035	1.57
Source concentration (µg/kg)		163,000 (top 5 ft)	7000 (0-0.5ft)
		160,000 (deeper than 5 ft)	190,000 (4-5 ft)
			140,000 (9-10 ft)
Chemical Parameters		Perchlorate	Perchlorate
Organic carbon partition coefficient (cm ³ /g)		NA	NA
Distribution coefficient (K _d) (cm ³ /g)		0	0
Henry's law constant (dimensionless)		0.024	0.024
Free air diffusion coefficient (cm ² /sec)		0.00001	0.00001
Aqueous solubility (µg/L)		50,000	50,000

Notes and Abbreviations:

^a Shortest distance to Goose Prairie Creek along the groundwater flow direction

µg/kg micrograms per kilogram

µg/L micrograms per liter

cm/sec centimeters per second

cm²/sec square centimeters per second

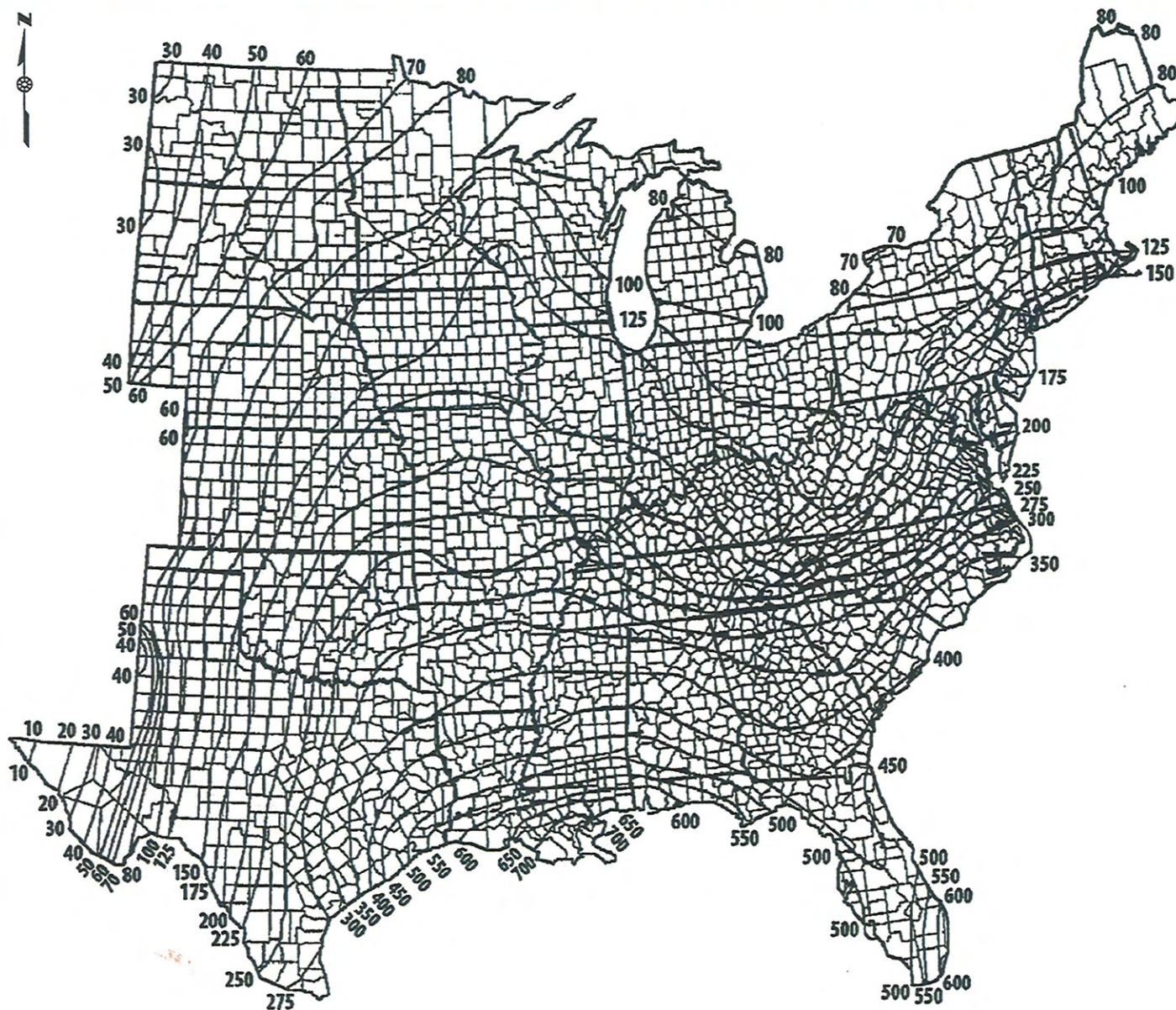
cm³/g cubic centimeters per gram

ft feet

NA not applicable

Plot Date: 02/05

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Lu	02/24/05 K. Everett	02/24/05 P. Srivastava	02/24/05 X:\Longhorn\GIS\workspace\BLU\MXD\iso_map.mxd



Note:
Units are hundreds of foot-tons-force
inches per hour per acre per year

Not to Scale

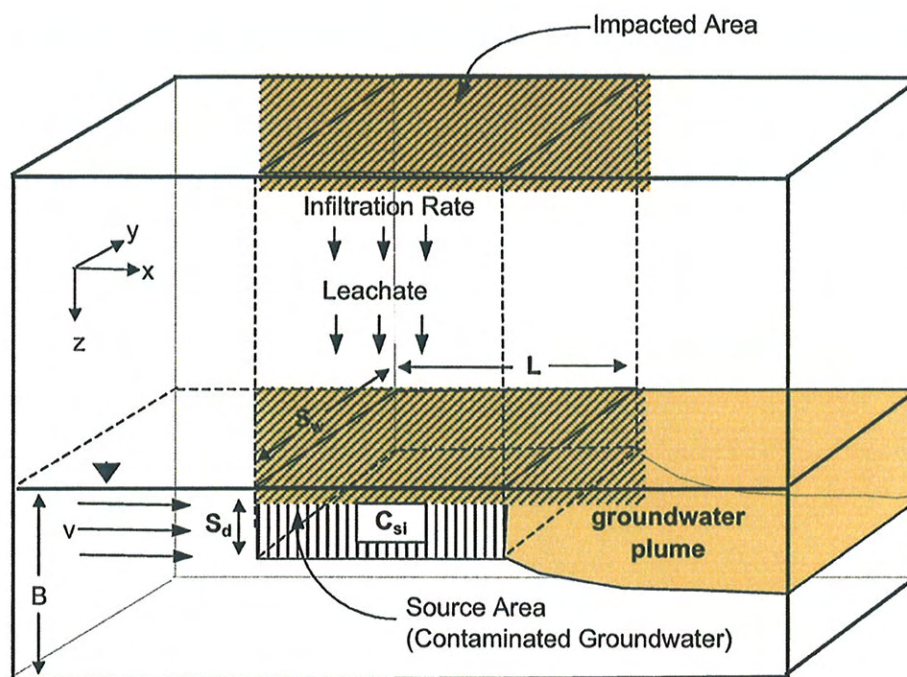


U.S. Army Corps of Engineers
Tulsa District
Tulsa, Oklahoma

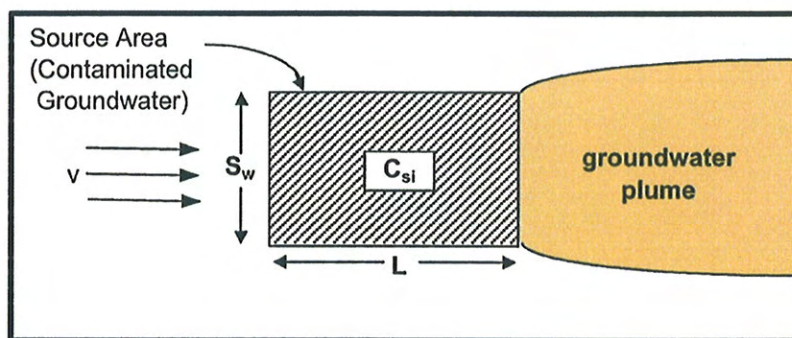
Figure 4-1
Isoerodent Map of Eastern United States
Modeling Report
Longhorn Army Ammunition Plant
Kamack, Texas

Reference: <<http://www.epa.gov/npdes/pubs/fact3-1.pdf>> (October, 2004)

Figure 4-2:
Schematic Description of Domenico's Model



SECTION



PLAN

ABBREVIATIONS USED: S_w = source width v = groundwater flow velocity
 S_d = source depth C_{si} = contamination source
 L = source length B = aquifer thickness

5.0 Modeling Results

The fate and transport modeling for the COCs at each site is summarized in **Sections 5.1 through 5.11**. **Section 5.12** provides a comparison of the modeling results with the data collected after the modeling was completed. **Table 5-1** summarizes results of calculations and modeling of the fate and transport of COCs present in soil and groundwater to surface water and sediments of creeks and bayous within LHAAP at each of the 11 sites evaluated. This table includes a summary of modeled pathways, the analytical model or equation utilized, COCs modeled and modeling results. Detailed information regarding input parameters, specific models used, and model output is presented separately for each site in **Appendices A through K**. **Appendix L** presents the results of modeling of soil to surface water and soil to groundwater pathways at three sites (LHAAP-35A[58], -46, and -48). **Appendix M** presents results of an elevation survey of creeks and bayous at LHAAP. Creek bottom elevations were compared with groundwater elevations to determine if the groundwater at a site would discharge to a nearby creek.

5.1 LHAAP-04

Calculations of maximum concentrations and DFs of perchlorate discharging into Goose Prairie Creek from soil and groundwater at LHAAP-04 were performed as follows: 1) modeling of soil perchlorate leachate in the vadose zone to underlying groundwater using VLEACHSM, 2) calculation of maximum concentrations of perchlorate in groundwater and the time of transportation before discharging to Goose Prairie Creek utilizing AT123D, and 3) calculation of perchlorate concentrations in surface soil that are protective of sediment and surface water due to erosion of soil by rainstorm generated runoff as described in the Technical Memorandum (Shaw, 2004a). Detailed calculations and results of modeling are included as **Appendix A**.

Summary of Calculation Results. A maximum perchlorate concentration of 163,000 micrograms per kilogram ($\mu\text{g/kg}$) was detected in soil that can be eroded by rainstorm-generated runoff to the nearest point of Goose Prairie Creek. The perchlorate levels found in soil (163,000 $\mu\text{g/kg}$) exceeded the calculated soil concentrations protective of sediment (71,400 $\mu\text{g/kg}$) and surface water (3.27 $\mu\text{g/kg}$).

Modeling of the leaching of perchlorate from the soil to groundwater indicated that perchlorate levels in groundwater as a result of soil leachate are lower than the calculated levels protective of surface water. Subsequent flow mixing and dilution of groundwater into the surface water of Goose Prairie Creek resulted in concentrations of perchlorate that are below the IAL of 4 $\mu\text{g/L}$. Mixing concentrations of perchlorate in Goose Prairie Creek are at 0.519 and 1.39 $\mu\text{g/L}$ for the 10-year and 100-year continuous source release scenarios, respectively.

5.2 LHAAP-12

Calculations of maximum concentrations and DFs of TCE, VC, and perchlorate potentially discharging into Central Creek from groundwater at LHAAP-12 were performed utilizing the Domenico equation. Detailed results of the calculations are included as **Appendix B**.

Summary of Calculation Results. The results of the Domenico equation calculations indicated that the maximum concentrations of TCE, VC, and perchlorate in groundwater at the POE into Central Creek are 16.23, 0.307, and 21.2 $\mu\text{g/L}$, respectively. Even prior to mixing and dilution, VC concentration is below the MCL of 2 $\mu\text{g/L}$. TCE and perchlorate concentrations decrease substantially with mixing and dilution to 0.03 and 0.038 $\mu\text{g/L}$, respectively. These levels are below the MCL for TCE and the IAL for perchlorate. The current maximum concentrations at the source: TCE (495 $\mu\text{g/L}$), VC (2.1 $\mu\text{g/L}$), and perchlorate (56 $\mu\text{g/L}$), are lower than the MSCs protective of surface water for all three COCs including TCE (49,500 $\mu\text{g/L}$), perchlorate (3,568 $\mu\text{g/L}$) and VC, the concentration of which is lower than the MSC protective of groundwater at POE even before mixing with surface water in the creek.

5.3 LHAAP-29

AT123D was utilized to predict the fate and transport of TCE, methylene chloride, 1,2-DCA, and perchlorate in groundwater at LHAAP-29. Detailed results of the modeling are included as **Appendix C**.

Summary of Modeling Results. Results of the modeling indicate that the three COCs; TCE, methylene chloride, and 1,2-DCA will not reach Central Creek. The COC perchlorate reaches the creek at 1,634 $\mu\text{g/L}$ in groundwater; however, perchlorate is mixed and diluted in surface water to a concentration of 2.74 $\mu\text{g/L}$, a level below the action level of 4 $\mu\text{g/L}$. The current maximum perchlorate concentration at the source, 61,400 $\mu\text{g/L}$, is lower than the MSC value protective of surface water, 89,635 $\mu\text{g/L}$.

5.4 LHAAP-35A(58)

Calculations of maximum concentrations and DFs of TCE, 1,1-DCE, PCE, RDX, and perchlorate in groundwater and the time of transportation before discharging to Goose Prairie Creek were performed utilizing AT123D. Detailed results of modeling are included as **Appendix D**.

Summary of Calculation Results. Results of the modeling indicated that except for RDX and perchlorate, the three COCs: TCE, 1,1-DCE, and PCE will not reach Goose Prairie Creek. For the RDX, the derived maximum concentration of 12.75 $\mu\text{g/L}$ at the POE is lower than the MSC (26 $\mu\text{g/L}$) and the observed RDX concentration at the site (88 $\mu\text{g/L}$) is less than the calculated MSC (179.4 $\mu\text{g/L}$). For the COC perchlorate, upon reaching the creek, perchlorate is mixed and

diluted to a concentration of 0.0075 µg/L, a level below the action level of 4 µg/L. The current maximum perchlorate concentration at the source at 36.9 µg/L is lower than the MSC protective of surface water of 4,920 µg/L.

5.5 LHAAP-35B(37)

The fate and transport of TCE, 1,1-DCE, and PCE in groundwater to Goose Prairie Creek was modeled utilizing AT123D. Detailed results of modeling are included as **Appendix E**.

Summary of Modeling Results. Results of the modeling indicated that PCE and 1,1-DCE will not appear in detectable levels at the POE. The maximum concentration of TCE (3.63 µg/L) at the POE is below the MCL (5 µg/L).

5.6 LHAAP-35C(53)

Calculations of perchlorate concentrations in surface soil that are protective of sediment and surface water due to erosion of soil by storm-generated runoff were performed as described in the Technical Memorandum (Shaw, 2004). In addition, AT123D was utilized to predict the fate and transport of TCE in groundwater at the site. Detailed results of the calculations and modeling are included as **Appendix F**.

Summary of Calculation Results. A maximum perchlorate concentration of 60.9 µg/kg was detected in soil that can be eroded by rainstorm-generated runoff to the nearest point in Central Creek. The level of perchlorate found in soil at the source is below the calculated soil concentrations protective of sediment (51,300 µg/kg) and surface water (130 µg/kg derived from a solute concentration of 625 µg/L). In addition, the calculated perchlorate concentration of 3.4 µg/L in the water at the downstream end of the affected property is lower than the action level of 4.0 µg/L.

Results of the modeling indicate that the maximum concentration of TCE at the POE is below the MCL in both Central Creek and Harrison Bayou. Even if the maximum concentration of TCE (7 µg/L) is placed at Central Creek and Harrison Bayou, the mixing concentrations of 7.9×10^{-4} and 4.2×10^{-5} µg/L, respectively, are much lower than the MCL of 5 µg/L. In addition, the maximum source concentration of 7 µg/L, is lower than the MSC of 8,861 µg/L.

5.7 LHAAP-46

The fate and transport of perchlorate in groundwater to Goose Prairie Creek – Middle was modeled utilizing AT123D. Detailed results of the calculations and modeling are included as **Appendix G**.

Summary of Calculation Results. Results of the modeling indicate that perchlorate will start to appear at the POE in the creek after 207 years and peak after 300 years at a concentration of 0.07 µg/L, which is lower than the IAL of 4 µg/L.

5.8 LHAAP-47

Calculations of perchlorate transport by eroded soil to the nearby Goose Prairie Creek, and simulation of the fate and transport of TCE, PCE, PCP, VC, and perchlorate in groundwater to the creek were performed for the site. Detailed results of the calculations are included as **Appendix H**.

Summary of Calculation Results. The calculated soil concentrations protective of surface water and sediment for perchlorate are 15.96 and 37,700 µg/kg, respectively. The current perchlorate level in soil at 180,000 µg/kg is not protective of surface water or sediment in nearby Goose Prairie Creek because the source levels are higher than the surface water and sediment protective values. The calculated perchlorate concentration of 45,100 µg/L in the water at the downstream end of the affected property is higher than the action level of 4.0 µg/L.

Simulation results indicate that TCE, PCE, and PCP will not exceed their respective MCLs at the POE in groundwater at Goose Prairie Creek. However, VC and perchlorate will appear at maximum concentrations of 46.1 and 66,820 µg/L, respectively, at the POE. After mixing and dilution in Goose Prairie Creek, VC and perchlorate will decrease to 0.0039 and 3.13 µg/L, respectively; values that are below the MCL (2.0 µg/L) for VC and the IAL (4.0 µg/L) for perchlorate. Note that perchlorate at the POE comes from two sources: (1) the groundwater plume; and (2) as leachate from soil. Source concentrations of VC and perchlorate at 127 and 82,900 µg/L are lower than the calculated MSCs protective of surface water at concentrations of 65,128 and 105,942 µg/L, respectively.

5.9 LHAAP-48

Calculations of maximum concentrations and DFs of TCE and perchlorate in groundwater and the time of transportation before discharging to Central Creek was performed using AT123D. Detailed results of modeling are included as **Appendix I**.

Summary of Calculation Results. LHAAP-48 is located on both sides of the tributary of Central Creek and monitoring locations are in close proximity with the tributary. Therefore it was assumed conservatively (worst-case scenario) that TCE and perchlorate are present at the POE in the tributary of the creek at maximum concentrations of 9 and 160 µg/L, respectively. Mixing calculation results indicate that concentrations of TCE (0.00018 µg/L) and perchlorate (0.0032 µg/L) in the tributary of Central Creek are lower than their respective MCL (5 µg/L) and the IAL (4 µg/L). Maximum observed source concentrations of TCE and perchlorate are lower than the MSCs protective of surface water.

5.10 LHAAP-50

AT123D was utilized to simulate the fate and transport of TCE, PCE, VC, 1,2-DCA, and perchlorate in groundwater to surface water. Detailed modeling results are included as **Appendix J**.

Summary of Modeling Results. Simulation results indicated that PCE and 1,2-DCA will not exceed their respective MCLs at the POE at Goose Prairie Creek. However, TCE, VC, and perchlorate will appear at the POE at maximum concentrations of 567.5, 16.8, and 17,840 µg/L, respectively. After mixing and dilution in Goose Prairie Creek, TCE, VC and perchlorate will decrease to 0.014, 4.22×10^{-4} , and 0.448 µg/L, respectively; values that are below the MCLs for TCE (5.0 µg/L) and VC (2.0 µg/L) and the IAL for perchlorate (4.0 µg/L). Maximum observed source concentrations of VC and perchlorate at 100 and 18,000 µg/L are lower than the MSCs protective of surface water, 473,934 and 160,714 µg/L, respectively.

5.11 LHAAP-67

AT123D was utilized to simulate the fate and transport of TCE, 1,2-DCA, 1,1-DCE, 1,1,1-TCA, and 1,1,2-TCA in groundwater to surface water. Detailed modeling results are included as **Appendix K**.

Summary of Modeling Results. Simulation results indicate that for the instantaneous source scenario, maximum concentrations for all chemicals were below their respective MCLs at the POE. However, for the continuous source scenario, except for 1,1-DCE and 1,2-DCA, all other chemicals appear at the POE at maximum concentrations that exceed their MCLs. The maximum concentrations of 1,1,1-TCA, 1,1,2-TCA, and TCE at the POE were 240.6 µg/L, 23.7 µg/L, and 21.6 µg/L, respectively. Upon mixing and dilution in the creek, the concentrations are diluted to well below their respective MCLs. The resultant mixing concentrations for 1,2-DCA, 1,1,1-TCA, 1,1,2-TCA, and TCE are 0.024, 1.459, 0.144, and 0.131 µg/L, respectively. In addition, the maximum observed source concentrations for the chemicals are well below their respective MSCs protective of surface water.

5.12 Comparison of Modeling Results to Recent Studies

Maximum Concentrations of COCs. The maximum concentrations of COCs at each site used during the modeling were based on previous investigations by other consultants. The data utilized during modeling was qualitatively compared with the most recent data collected by Shaw during data gaps investigation activities (Shaw, 2005). Results of the comparison of the data indicated that except for two chemicals, methylene chloride at LHAAP-29 and TCE at LHAAP-35A(58), most of the chemical concentrations were below previously detected levels. The concentrations of methylene chloride and TCE detected at LHAAP-29 and

LHAAP-35A(58), respectively, during the data gaps investigation (Shaw, 2005) were below the MSCs calculated in this report.

Perchlorate. Recent studies by the National Academy of Sciences (NAS) recommended the maximum daily dose of perchlorate at 0.0007 milligrams per kilogram of body weight per day compared with EPA's 0.00003 mg/kg. The safe dosage recommended by NAS is 23 times higher than what the EPA had initially suggested based on its previous assessment. The maximum daily dose recommended by NAS corresponds to a groundwater action level approximately five times the Texas IAL standard of 4 µg/L indicating that the modeling presented in this report is highly conservative in protecting surface water bodies at LHAAP from perchlorate.

Table 5-1
Summary of Modeling Results

Site	Medium	Modeled Path	Analytical Model	COC	Regulatory Limits ^a (µg/L)	Derived Concentration Downstream of Affected Area in Creek (from Surface Soil) (µg/L)	Maximum Conc in GW at Creek (µg/L)	MSC Based on DF in GW at Creek Instantaneous (µg/L)	Maximum Conc in GW at Creek Continuous (MSP) ^b (µg/L)	MSC Based on DF in GW at Creek (µg/L)	Mixing Conc in Creek (µg/L)	MSC Evaluated at Point of Discharge (µg/L)	Results Protective of Surface Water
LHAAP-4	Soil	Surface soil to surface water - Goose Prairie Creek Surface soil to sediment - Goose Prairie Creek Soil leachate to groundwater Groundwater to surface water - Goose Prairie Creek	Tech Memo [Shaw (2004)] VLEACHSM AT123D	Perchlorate	4.0 (IAL)	7800 > 4.0 (IAL)			3,604	84.4	0.519	584,971	No No Yes
LHAAP-12	Groundwater	Groundwater to surface water - Central Creek	Dominico Equation	Trichloroethene Vinyl Chloride Perchlorate	5.0 (MCL) 2.0 (MCL) 4.0 (IAL)		16.23 0.307 21.2	152.45 13.67 10.56			0.03 0.038	82,500 5,895	Yes Yes Yes
LHAAP-29	Groundwater	Groundwater to surface water - Central Creek	AT123D	Trichloroethene 1,2-dichloroethane Methylene Chloride Perchlorate	5.0 (MCL) 5.0 (MCL) 5.0 (MCL) 4.0 (IAL)		0 0 0 1.634	Infinity Infinity Infinity 150.4			NA NA NA 2.74	NA NA NA 89,635	Yes Yes Yes Yes
LHAAP-35A (LHAAP-58)	Groundwater	Groundwater to surface water - Goose Prairie Creek	AT123D	Trichloroethene 1,1-dichloroethene Tetrachloroethene RDX Perchlorate	5.0 (MCL) 7.0 (MCL) 5.0 (MCL) 26.0 (MSC) 4.0 (IAL)				0 0 0 12.75 12.43	Infinity Infinity Infinity 179.4 11.9	NA NA NA NA 0.0075	NA NA NA NA 4,920	Yes Yes Yes Yes Yes
LHAAP-35B (LHAAP-37)	Groundwater	Groundwater to surface water - Goose Prairie Creek	AT123D	Trichloroethene 1,1-dichloroethene Tetrachloroethene	5.0 (MCL) 7.0 (MCL) 5.0 (MCL)		3.63 0 0.02	454.5 infinity 8,500					Yes Yes Yes
LHAAP-35C (LHAAP-53)	Soil	Surface soil to sediment - Central Creek or Harrison Bayou Surface soil to surface water - Central Creek or Harrison Bayou	Tech Memo [Shaw (2004)] Tech Memo [Shaw (2004)]	Perchlorate	25 mg/kg (PCL) ^c 4.0 (IAL)	Derived Soil PCL=51.3 mg/kg >> 0.061mg/kg at source 3.4 < 4.0 (IAL)							Yes (sediment) Yes Yes Yes
	Groundwater	Groundwater to surface water - Central Creek or Harrison Bayou	AT123D	Trichloroethene	5.0 (MCL)		7 ^d	5 ^d			4.2E-05 (HB) 7.9E-04 (CC)	166,667 (HB) 8,861 (CC)	Yes Yes Yes
LHAAP-46	Groundwater	Groundwater to surface water - Goose Prairie Creek -Middle	AT123D	Perchlorate	4.0 (IAL)		0.07	1,716			NA	NA	Yes
LHAAP-47	Soil	Subsurface soil to sediment - Goose Prairie Creek Subsurface soil to surface water - Goose Prairie Creek Soil leachate to groundwater	Tech Memo [Shaw (2004)] Tech Memo [Shaw (2004)] VLEACHSM	Perchlorate	25 mg/kg (PCL) ^c 4.0 (IAL)	Derived Soil PCL=37.7 mg/kg << 180 mg/kg at source 45100 >> 4.0 (IAL)							No (sediment) No
	Groundwater	Groundwater to surface water - Goose Prairie Creek	AT123D	Trichloroethene Tetrachloroethene Pentachlorophenol Vinyl Chloride Perchlorate	5.0 (MCL) 5.0 (MCL) 1.0 (MCL) 2.0 (MCL) 4.0 (IAL)		1.08 0 0 46.1 NE	136,110 Infinity Infinity 5.5 NE			NE NE NE 0.0019 2.8	NE NE NE 65,128 105,942	Yes Yes Yes Yes Yes
LHAAP-48	Groundwater	Groundwater to surface water - Central Creek	AT123D	Trichloroethene Perchlorate	5.0 (MCL) 4.0 (IAL)		9 160	NE NE			1.80E-04 1.30E-03	1.38E+07 2.00E+05	Yes Yes
LHAAP-50	Groundwater	Groundwater to surface water - Goose Prairie Creek	AT123D	Trichloroethene Tetrachloroethene 1,2-dichloroethane Vinyl Chloride Perchlorate	5.0 (MCL) 5.0 (MCL) 5.0 (MCL) 2.0 (MCL) 4.0 (IAL)		567.5 0 0 16.8 17,840	194 Infinity Infinity 11.9 4.04			0.007 NE NE 4.22E-05 0.448	7,857,143 NE NE 73,934 160,714	Yes Yes Yes Yes Yes
LHAAP-67	Groundwater	Groundwater to Central Creek	AT123D	Trichloroethene 1,2-dichloroethane 1,1-dichloroethene 1,1,1-trichloroethane 1,1,2-trichloroethane	5.0 (MCL) 5.0 (MCL) 7.0 (MCL) 200 (MCL) 5.0 (MCL)		0.13 0.06 0 2.39 0.23	242 2250 Infinity 150,628 717	21.6 3.9 0.15 240.6 23.7	1.46 34.5 14,778 1,500 6.95	0.131 0.024 NE 1.459 0.144	240 5,625 NE 246,744 1,146	Yes Yes Yes Yes Yes

Notes and Abbreviations:

Shaw E & I, 2004, Final Technical Memorandum - Modeling Approach for Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas, March 2004

^a Value represents the maximum concentration limit (MCL), the TCEQ risk-based medium specific concentration (MSC) for industrial use, or the TCEQ interim action level (IAL) for perchlorate

^b Assume continuous source for 10 years

^c Sediment PCL for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002

^d Assume TCE discharge to both Harrison Bayou and Central Creek, a worst-case scenario.

CC Central Creek
COC contaminant of concern
Conc concentration
DF dilution factor
GPC Goose Prairie Creek
GW groundwater
HB Harrison Bayou
MSC medium-specific concentration
NA Not applicable
NE Not estimated

6.0 *Additional Evaluations of Chemicals in Soil at LHAAP-35A(58), -46, and -48*

In addition to the modeling and calculations for the chemicals of concern presented in **Section 5.0** of this report, the fate and transport for bis(2-ethylhexyl)phthalate at LHAAP-35A(58) and LHAAP-46, and vinyl chloride and PCE at LHAAP-48 in soil was evaluated. Although risk assessment results indicated that these chemicals do not pose a risk to human health (Jacobs, 2002), for a very conservative approach, the evaluation of the effect of these chemicals on nearby surface water and sediment was conducted. The three chemicals were detected at elevated concentrations in the top 2 feet of the soil. Bis(2-ethylhexyl)phthalate was detected in soil at a concentration of 200,000 and 690 µg/kg at LHAAP-35A(58) and -46, respectively. Vinyl chloride and PCE were detected in surface soil at LHAAP-48, at concentrations of 497 and 204 µg/kg, respectively.

Table 6-1 presents a summary of modeled pathways, the analytical model, COCs modeled and modeling results. Detailed calculations and the results of modeling are included as **Appendix L**.

6.1 *LHAAP-35A(58)*

Calculation of bis(2-ethylhexyl)phthalate concentrations in soil that are protective of sediment and surface water due to erosion of soil by rainstorm-generated runoff to nearby Goose Prairie Creek was performed. Modeling of soil bis(2-ethylhexyl)phthalate leachate in the vadose zone to underlying groundwater using VLEACHSM was also conducted.

Summary of Calculation Results. A maximum bis(2-ethylhexyl)phthalate concentration of 200,000 µg/kg was detected in soil eroded by rainstorm-generated runoff to the nearest point of Goose Prairie Creek. The level of bis(2-ethylhexyl)phthalate found in soil at the source is below the calculated soil concentrations protective of sediment (303,500 µg/kg). In addition, the calculated bis(2-ethylhexyl)phthalate concentration of 8,430 µg/L in the water at the downstream end of the affected property is higher than the MSC of 6.0 µg/L.

The current concentration of bis(2-ethylhexyl)phthalate in the soil at LHAAP-35A(58) is protective of sediment but not protective of surface water in Goose Prairie Creek.

6.2 *LHAAP-46*

Calculations of bis(2-ethylhexyl)phthalate concentrations in surface soil that are protective of sediment and surface water due to erosion of soil by storm-generated runoff to nearby Goose Prairie Creek – Middle were performed.

Summary of Calculation Results. Bis(2-ethylhexyl)phthalate in surface soil at a concentration of 690 µg/kg is protective of sediment and surface water.

6.3 LHAAP-48

Calculations of vinyl chloride and PCE concentrations in surface soil that are protective of sediment and surface water due to erosion of soil by storm-generated runoff to nearby Central Creek were performed. In addition, modeling of leaching of vinyl chloride and tetrachloroethane (PCA) from soil to groundwater was performed utilizing VLEACHSM.

Summary of Calculation Results. Vinyl chloride and PCA in soil, though elevated in concentration, will not adversely impact surface water when the COCs migrate vertically to groundwater because their mixing concentrations in groundwater are already below their respective MCLs. However, when the soil is eroded and transported to surface water, the vinyl chloride concentration is not protective of surface water.

Table 6-1
Summary of Additional Modeling of Chemicals in Soil at LHAAP-35A(58), -46, and -48

Site	Medium	Modeled Path	Analytical Model	COC	Regulatory Limits (a)	Derived Concentration Downstream of Affected Area in Creek (from Surface Soil)	Maximum Conc in GW at Creek Instantaneous	MSC GW & Creek	Maximum Conc in GW at Creek Continuous(b)	MSC GW & Creek	Mixing Conc in Creek	MSC Point of Discharge	Results Protective of Surface Water
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	
LHAAP-35A (58)	Soil	Surface soil to sediment - Goose Prairie Creek	Tech Memo (Shaw, 2004)	Bis(2-ethylhexyl)phthalate	240 mg/kg (PCL) ^(c)	Derived Soil PCL=303.5 mg/kg >> 200mg/kg at source 8430 > 6.0 (MSC)							Yes (Sediment)
		Surface soil to surface water - Goose Prairie Creek	Tech Memo (Shaw, 2004)	Bis(2-ethylhexyl)phthalate	6.0 (MSC)								No
		Soil leachate to groundwater	VLEACHISM										
LHAAP-46	Soil	Subsurface soil to sediment - Goose Prairie Creek - Middle	Tech Memo (Shaw, 2004)	Bis(2-ethylhexyl)phthalate	240 mg/kg (PCL) ^(c)	Derived Soil PCL expected to be much greater than 304 mg/kg (see Site 35A), therefore much greater than 0.690 mg/kg at source 4.4 < 6.0 (MSC)							Yes (Sediment)
		Subsurface soil to surface water - Goose Prairie Creek - Middle	Tech Memo [Shaw (2004)]	Bis(2-ethylhexyl)phthalate	6.0 (MSC)								Yes
LHAAP-48	Soil	Surface soil to surface water/sediment - Central Creek	Tech Memo [Shaw (2004)]	Vinyl Chloride	36 mg/kg (PCL) ^(c)	Derived Soil PCL=38 mg/kg >> 0.497 mg/kg at source 27.5 > 2.0 (MCL)							Yes (Sediment)
				Tetrachloroethene	1000 mg/kg (PCL) ^(c)								Derived Soil PCL=1118 mg/kg >> 0.204 mg/kg at source 8.3 < 5.0 (MCL)
	Soil	Soil leachate to groundwater	VLEACHISM	Vinyl Chloride Tetrachloroethene		No (Surface Water) Yes Yes							

Notes:
Shaw, 2004, "Final Technical Memorandum - Modeling Approach for Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas." March 2004
(a) Value represents whether the MCL (maximum concentration limit), the TCEQ risk-based MSC (medium specific concentration) for industrial use, or the TCEQ interim action level for perchlorate (IAL)
(b) Assume continuous sources for 10 years
(c) Sediment PCL for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002
(d) Assume TCE source is at both Harrison Bayou and Central Creek - a worst case scenario.

CC Central Creek
COC contaminant of concern
GPC Goose Prairie Creek
HB Harrison Bayou
MCL maximum concentration limit
MSC medium-specific concentration
NA Not Applicable
NE not estimated
PCL protective concentration limit
µg/L micrograms per liter

7.0 Conclusions

Chemicals of Concern in Soil

Generally, chemicals in soil at the LHAAP sites evaluated in this report are present at concentrations lower than MSCs that are protective of surface water and sediment. Perchlorate at sites LHAAP-04 and LHAAP-47 is present in erodable soil at values that exceed levels protective of both sediment and surface water in nearby Goose Prairie Creek. Although human health risk assessments indicated that bis(2-ethylhexyl)phthalate at LHAAP-35A(58), vinyl chloride and PCE at LHAAP-48 do not pose a risk, these chemicals are present in erodable soil at levels that exceed values protective of surface water in nearby Goose Prairie Creek and Central Creek, respectively. Other chemicals present in the soil at these LHAAP sites will not adversely impact surface water or sediment.

Chemicals of Concern in Groundwater

Eleven COCs were modeled to estimate migration of chemicals in groundwater from a site to a downgradient location of discharge to surface water. Results of modeling at the 11 sites indicate that the COCs appear at POE in surface water at values that are either lower than MCLs or IAL or, upon mixing and dilution with surface water, COC levels decrease to concentrations below MCLs or IAL. Chemicals present in groundwater will not adversely impact sediment or surface water.

8.0 References

The references that follow support the main volume modeling report as well as Appendices A through M:

ASTM, 1995, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites*, E-1739-95.

ASTM, 1999, *RBCA Fate and Transport Models: Compendium and Selection Guidance*, Technical & Professional Training.

Business Publishers, Inc., 2003, *Solving the Perchlorate Problems: Assessing the Risk, Seeking a Standard and Innovative Treatment Methods*.

Domenico, P.A. and F.W. Schwartz, 1998, *Physical and Chemical Hydrogeology-Second Edition* John Wiley & Sons, Inc.

Dynamac Corporation, 1995, *VLEACHSM - Vadose Zone Leaching and Saturated Zone Mixing Model, version 1.0a*, developed for Robert S. Kerr Environmental Research Laboratory Center for Subsurface Modeling Support, May.

Feenstra, S., D.M. Mackay and J.A. Cherry, 1991, *A Method for Assessing Residual NAPL Based on Organic Chemical Concentration in Soil Samples*, Ground Water Monitoring and Remediation, Spring.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M., Meylan, and E.M. Michalenko, 1991, *Environmental Degradation Rates*, Lewis Publishers, Inc.

Jacobs Engineering Group, Inc. (Jacobs), 2001a, *Preliminary Draft, Third Quarter Data Summary Report for the Investigation at the Longhorn Army Ammunition Plant, Karnack, Texas*, April.

Jacobs, 2001b, *Final Remedial Investigation Report (Volume 1-3) for the Group 2 Sites: Sites 12, 17, 18/24, 29, and 32, Longhorn Army Ammunition Plant, Karnack, Texas*, April.

Jacobs, 2001c, *Preliminary Draft-Third Quarter Data Summary Report for the Perchlorate Investigation at the Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas*, April.

Jacobs, 2002a, *Final Remedial Investigation Report (Volume 1 & 2) for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50, 60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas*, January.

Jacobs, 2002b, *Final Remedial Investigation Report Addendum for the Group 4 Sites, Sites 04, 08, 67 and Hydrocarbon Study, Longhorn Army Ammunition Plant, Karnack, Texas*, February.

Jacobs, 2002c, *Draft Final Feasibility Study for the Group 2 Sites, Sites 12, 16, 17, 18/24, 29, 32, and 49, Longhorn Army Ammunition Plant, Karnack, Texas*, May.

Jacobs, 2002d, *Draft Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50, 60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas*, June.

Jacobs, 2002e, *Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 2 Sites, Sites 12, 17, 18/24, 29, 32, and 49, Harrison Bayou and Caddo Lake, Longhorn Army Ammunition Plant, Karnack, Texas*, August.

Jacobs, 2002f, *Draft Feasibility Study for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunders Branch, Central Creek, and Caddo Lake, Longhorn Army Ammunition Plant, Karnack, Texas*, August.

Longhorn Army Ammunition Plant (LHAAP), 2002, LHAAP IAP, Meeting Minutes — Data Quality Objective Workshop, Group 2, Dallas, Texas, June 12-13.

LHAAP, 2003a, LHAAP IAP, Minutes — Surface Water Standards Meeting, Workshop, Group 2, Texas Commission on Environmental Quality, Austin, Texas, January 22.

LHAAP, 2003b, LHAAP IAP, Meeting Minutes - Data Quality Objective Workshop, Group 4 Sites, Austin, Texas, April 29-30.

LHAAP, 2003c, LHAAP Monthly Manager's Meeting, Dallas, Texas, November 19.

Lindeburg, M.R., 1989, *Civil Engineering Reference Manual, Fifth Edition*, Professional Publications, Inc., Belmont, California.

Miller, G. and van der Leeden Troise, 1973, *Water Atlas of the United States*, A Water Information Publication, NY.

Montgomery, J.H., 2000, *"Groundwater Chemicals, Desk Reference (Third Edition)"*, Lewis Publishers.

Oak Ridge National Laboratory, 2004, "Risk Assessment Information System," <<http://risk.lsd.ornl.gov>> (October 2004).

Schueler, T. R., 1987, *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*, Document No. 87703, Metropolitan Washington Council of Governments, Washington, D. C.

Shaw Environmental, Inc. (Shaw), 2004a, *Final Technical Memorandum, Modeling Approach for Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, March.

Shaw, 2004b, *Revised Final Feasibility Study, Site 12 Group 2, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, August.

Shaw, 2005, *Draft Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, January.

Solutions to Environmental Problems, Inc., 2003, *Draft Final Project Report Plant-Wide Perchlorate Investigation, Longhorn Army Ammunition Plant, Karnack, Texas*, Vol. 1, March.

Texas Commission on Environmental Quality, 2003, *Procedures to Implement the Texas Surface Water Quality Standards*, January, Water Quality Division, RG-194

Texas Natural Resources Conservation Commission (TNRCC) (now the Texas Commission on Environmental Quality, 1998, *Implementation of the Existing Risk Reduction Rule*, Memorandum from Ronald R. Peede to Remediation Division Staff, July 23. This memorandum is commonly referred to as the “consistency Memorandum” and may be obtained on-line with subsequent TCEQ updates at <<http://www.tnrcc.state.tx.us/permitting/rrr.htm>> (March 2004).

TNRCC, 2002, “Texas Risk Reduction Program Rule,” Texas Register, May.

Toy, T.J and G.R. Foster, 1998, *Guidelines for the Use of Revised Universal Soil Loss Equation (RUSLE), Version 1.06, on Mined Lands, Construction Sites, and Reclaimed Lands*, Office of Surface Mining.

U.S. Department of Agriculture (USDA), 1996, *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*, AH 703, July.

U.S. Environmental Protection Agency (USEPA), 1985, *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water*, Revised 1985, EPA-600-6/85-002a, Washington D.C.

USEPA, 1988, *Selection Criteria for Mathematical Models Used in Exposure Assessments: Ground-Water Models*, EPA 600/8-88/075, May.

USEPA, 1994, *Ground-Water Modeling Compendium*, EPA 500-B-94-004, July.

USEPA, 2001, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, EPA/OSWER 9355.4-24, March.

USEPA, National Center for Environmental Assessment, 2002, *Perchlorate Environmental Contamination: Toxicological Review and Risk Characterization Based on Emerging Information*, External Review Draft.

Wischmeier, W.H. and D. D. Smith, 1978, *Predicting Rainfall-Erosion Losses – A Guide to Conservation Planning*, U. S. Department of Agriculture Handbook 37.

Yeh, G. T., 1987, AT123D: *Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System*, Pennsylvania State University.

Zheng, C, 1992, *MT3D – A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater System*, S.S. Papadopoulos & Associates, Inc.

Appendix A

***LHAAP-04 Calculation of Maximum Concentrations and
Dilution Factors of Contaminants Discharged to Goose Prairie
Creek from Soil and Groundwater***

Table of Contents

List of Tables	ii
List of Figures	ii
1.0 Introduction	1-1
2.0 Modeling	2-1
2.1 Leachate Modeling	2-1
2.1.1 Assumptions and Model Inputs	2-1
2.1.2 Model Results.....	2-2
2.1.3 Dilution Factor	2-3
2.2 Groundwater Modeling	2-3
2.2.1 Input Parameters.....	2-3
2.2.2 Modeling Results and Dilution Factors	2-5
2.2.3 Dilution in Goose Prairie Creek	2-5
3.0 Soil Concentration Protective of Sediment and Surface Water	3-1
3.1 Perchlorate Concentration in Erodable Soil Protective of Sediment	3-1
3.1.1 Soil Loss Calculation	3-1
3.1.2 Calculate ^{Sed} Soil MSC	3-3
3.2 Perchlorate Concentration in Erodable Soil Protective of Surface Water	3-4
4.0 Summary and Conclusions	4-1
5.0 References	5-1

List of Tables

Table 1	Calculated Dilution Factor for Four Scenarios. Leaching of Perchlorate from Soil, LHAAP-04
Table 2	Summary of Simulated Perchlorate Maximum Concentrations and MSCs at Goose Prairie Creek (722 feet Downgradient from Source) Discharged from Groundwater
Table 3	Calculation of Flow Discharge in Goose Prairie Creek
Table 4	RUSLE Calculation Result for LHAAP-04 – Affected Area
Table 5	RUSLE Calculation Result for LHAAP-04 – Total Area

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	LHAAP-04 Wet Season Sampling Event (March 2002) Soil Analytical Data
Figure 3A	Shallow Groundwater Elevation Contour Map (December 1998 Data)
Figure 3B	Shallow Groundwater Contour Map (September 2000 Data)
Figure 4	Mixing Concentration in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-04
Figure 5	Mixing Concentration in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-04
Figure 6	Mixing Concentration in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-04
Figure 7	Mixing Concentration in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-04
Figure 8	Perchlorate Concentrations in Groundwater Contributed by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek (722 feet from source), LHAAP-04
Figure 9	Perchlorate Concentrations in Groundwater Contributed by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek (722 feet from source), LHAAP-04
Figure 10	7Q2 Low Flow Analysis, Probability vs Flow Discharge for Goose Prairie Creek based on December 1999 to March 2000 Flow Derivation

1.0 Introduction

LHAAP-04 is located in the northwestern portion of the LHAAP facility with LHAAP-35A(58) to the northwest, LHAAP-49 to the southwest, and LHAAP-5 to east (**Figure 1**). LHAAP-04 was referred to as the Pilot Waste Water Treatment Plant where waste water from sumps throughout the facility was treated. This waste water plant was removed and closed in 1998.

The chemical of concern (COC) in the soil at LHAAP-04 is perchlorate. Elevated perchlorate concentrations at 163,000 µg/kg and 160,000 µg/kg were detected in soil samples collected from sampling location 04SS06 (**Figure 2**) at depth intervals of 0.0 to 0.5 feet and 1.0 to 2.0 feet below ground surface, respectively, in March 2002 (Solution to Environmental Problems, Inc. [STEP], 2003). Perchlorate was detected in groundwater at a concentration of 3.98 µg/L in monitoring well 04WW01 (Table 2-3 — STEP, 2003). Since this perchlorate concentration in groundwater is below the Texas interim action level (IAL) of 4 µg/L, it is not necessary to model this contaminant based solely on the current detected concentration in groundwater. However, because of the elevated concentrations in the vadose zone in the plume area and also the shallow depth to groundwater of approximately 5 feet, perchlorate leachate must be considered; consequently, the groundwater to surface water pathway must be modeled. No other contaminant was considered as a COC for modeling.

The surface water body closest to LHAAP-04 is Goose Prairie Creek, approximately 722 feet to the south. Goose Prairie Creek flows from west to east, southeast and northeast to Caddo Lake. Groundwater flows to the east in general, however, localized flow direction at LHAAP-4 and its vicinity may change from time to time as shown on **Figures 3A** and **3B**. Recent data gaps investigation activities indicated that groundwater flows to the southwest, southeast, and east. Contaminant particles in the groundwater at LHAAP-04 would not reach Goose Prairie Creek until approximately 7,000 feet to the east, based on December 1998 water level measurements. However, contaminants would travel south and enter Goose Prairie Creek 722 feet from the site based on September 2000 measurements (**Figure 3B**). Note that groundwater could also flow to the north, which would take a much longer route to Goose Prairie Creek. Therefore, the shortest distance for contaminants to travel 722 feet to Goose Prairie Creek was used in this calculation as a worst-case scenario.

The purpose of the calculation was to estimate: (1) perchlorate leachate to the groundwater from soil; (2) perchlorate transport from groundwater to surface water (Goose Prairie Creek); and (3) perchlorate transport from surface soil to Goose Prairie Creek. The maximum concentrations in sediment and in surface water as well as the dilution factors (DFs) of perchlorate were calculated, and, thereby, the media-specific concentrations (MSCs) from soil to sediment and from soil to surface water were developed.

2.0 Modeling

The objectives of this modeling effort were achieved by applying two computer codes VLEACHSM and AT123D.

2.1 Leachate Modeling

The VLEACHSM model was employed to obtain the leachate mixing concentration hydrograph in groundwater at LHAAP-04.

2.1.1 Assumptions and Model Inputs

Because of the uncertainty of the input parameters, conservative values were used and assumptions were made as described below:

- **Contaminant Source.** Perchlorate in soil is the only contaminant source at LHAAP-04. Because of the uncertainty of the time perchlorate continues to dissolve and be released to groundwater, two scenarios were considered in the current modeling using VLEACHSM: continuous constant-source release for 10 years and 100 years.
- **Source Area.** Perchlorate was detected in soil at sampling location 04SS06 with the highest concentration of 163,000 $\mu\text{g/kg}$. Perchlorate was also detected at soil sampling locations 04SS03 and 04SS05 with concentration ranging from 9,340 $\mu\text{g/kg}$ to 10,000 $\mu\text{g/kg}$ within 100 feet from 04SS06 (see **Figure 2**). In order to reduce the number of simulation times and to obtain conservative results, the simulated column with perchlorate source was assumed to be 5 feet by 5 feet in area and 5 feet in depth at 04SS06 only; applying the maximum soil concentration of 163,000 and 160,000 $\mu\text{g/kg}$ at different depths. The simulated results were then applied to the entire area of 120 feet (east-west) by 100 feet (north-south); i.e., the area of the detected soil area (**Figure 2**) in groundwater as affected area. Therefore, simulations for other columns at LHAAP-04 were avoided.
- **Depth to Groundwater.** No land survey data and geologic cross sections are available for this site. Therefore the adjacent site data (Site 35A) are used. The land surface elevation is approximately 214 feet (msl) (Jacobs, 2002a). The average groundwater elevation measured in December 1998 at LHAAP-4 was 209 feet (msl) (**Figure 3A**). Therefore, the depth to groundwater is 5 feet.
- **Chemical Parameters.** Because perchlorate is kinetically nonlabile (i.e., the reduction of the central chlorine atom occurs extremely slowly) and sorption or natural chemical reduction in the environment is not significant, perchlorate is exceedingly mobile in aqueous systems and can persist for many decades under typical groundwater and surface water conditions (USEPA, 2002). Hence, the water-soil partition coefficient (k_d) and degradation rate for perchlorate were assumed to be zeros. The Henry's law constant, diffusivity in air, and solubility of perchlorate were not available. Therefore, a conservative value of zero was assumed for the Henry's

law constant and diffusivity in air, and 200,000 mg/L was assumed for the solubility, assuming a worst-case scenario with ammonium perchlorate.

- **Dispersivities.** The longitudinal dispersivity was calculated based on the following equation (Dynamac Corporation, 1995):

$$\alpha_L = 2.554 \times 10^{-4} L_u^{3.811} \quad (L_u = 5 \text{ feet, depth of the column}) \quad \text{Equation A1}$$

$$= 0.118 \text{ ft}$$

$$\text{and the vertical dispersivity } \alpha_v = 0.3 \alpha_L = 0.035 \text{ ft} \quad \text{Equation A2}$$

- **Darcy's velocity.** Darcy's velocity (Dv) is required by VLEACHSM.

$$Dv = ki \quad (k = \text{hydraulic conductivity and } i = \text{hydraulic gradient}) \quad \text{Equation A3}$$

Because there is only one hydraulic conductivity value (3.5×10^{-5} cm/sec) derived from a slug test for LHAAP-04, the hydraulic conductivity, k, was therefore based on a slug test at the neighboring site LHAAP-35A (formerly LHAAP-58) (Table 5-1 — Jacobs, 2002a). The average value for k was calculated to be 6.36×10^{-4} cm/sec. The hydraulic gradient of 0.0072 was based on the potentiometric surface map constructed for the December 1998 water level measurement (Jacobs, 2002a). Therefore, Dv = 4.74 ft/year.

- **Recharge.** This input parameter has a high degree of uncertainty. Because the soil at the site is mainly clayey material (silty clay and clay) in the shallow subsurface (Jacobs, 2000a), the infiltration rate is very low. In this model, two scenarios of recharge to groundwater were assumed: 0.5 inch/year and 1.0 inch/year.

2.1.2 Model Results

The simulation results for four scenarios are graphically presented in **Figures 4** through **7**, showing the mixing concentration of perchlorate in groundwater contributed by soil leachate. These four scenarios are:

- **Scenario 1:** Continuous source release for 10 years with 0.5 in/yr of recharge (**Figure 4**). The maximum concentration is 35,700 µg/L.
- **Scenario 2:** Continuous source release for 10 years with 1.0 in/yr of recharge (**Figure 5**). The maximum concentration is 75,900 µg/L.
- **Scenario 3:** Continuous source release for 100 years with 0.5 in/yr of recharge (**Figure 6**). The maximum concentration is 45,000 µg/L. Because of the continuous source supply towards the downgradient portion of the site, the maximum concentration is maintained at 45,000 µg/L after 35 years.
- **Scenario 4:** Continuous source release for 100 years with 1.0 in/yr of recharge (**Figure 7**). The maximum concentration is 78,200 µg/L and stays at this concentrations after 15 years.

The above modeling results show that a continuous source release for 100 years yields a higher and sustainable maximum concentration in groundwater. Furthermore, the higher the recharge rate the higher the maximum concentration.

2.1.3 Dilution Factor

The highest COC concentration in time after mixing of the leachate with the groundwater was used as $Conc_{mix}$ in mg/L, then DF was calculated by:

$$DF = \frac{Conc_{source}}{Conc_{mix}} \quad \text{Equation A4}$$

where $Conc_{source}$ is the maximum COC concentration in the leachate in mg/L. $Conc_{source}$ was calculated based on the maximum soil concentration of the COC, $Conc_{soil}$, in mg/kg (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} * \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation A5}$$

where:

- ρ_b = bulk density of soil = assumed 1.7 g /cm³
- k_d = distribution coefficient = Assumed 0.0 cm³/g
- ϕ_w = water-filled porosity = 0.35
- ϕ_a = air-filled porosity = assumed 0.15
- H_c = Henry's law coefficient = assumed 0.0 (dimensionless)

$$Conc_{source} = \frac{163 * 1.7}{(0.35 + 0.0 * 0.15)} = 791,700 \text{ } \mu\text{g/L}$$

The dilution factors for the four scenarios are summarized in **Table 1**.

2.2 Groundwater Modeling

Although perchlorate was detected in groundwater at a low concentration of 3.98 $\mu\text{g/L}$, the currently elevated perchlorate concentrations in soil and the short vertical distance to groundwater (5 feet) may cause the generation of a leachate from soil, which may cause perchlorate levels in groundwater to increase with time as shown in **Table 1** and **Figures 4** through **7**. Therefore, fate and transport of perchlorate from the groundwater to the surface water was modeled using AT123D.

2.2.1 Input Parameters

The input data for the groundwater model are described as follows:

- **Contaminant source.** Conservatively, perchlorate source contributed by leachate from the vadose zone was considered under two scenarios (i.e., Scenarios 2 and 4 in the vadose zone modeling): 10-year and 100-year continuous sources, both with a recharge rate of 1.0 inch per year. The leachate mixing concentration hydrographs generated by VLEACHSM were used as inputs to the groundwater model – AT123D. Seven discretized values of the mixing concentration hydrographs (**Figures 5 and 7**) at different time periods, including the maximum concentrations (75,000 µg/L for 10-year continuous source release and 78,200 µg/L for 100-year continuous source release), were translated to a release rate (kg/hour) by multiplying these discretized values with the the recharge rate and the plume area of 120 feet by 100 feet (see below).
- **Source area.** While the source area in the soil was assumed to be 5 feet x 5 feet with 160,000 µg/kg to 163,000 µg/kg (corresponding to $Conc_{source} = 791,700 \mu\text{g/L}$ per Equation A5) in the upper 2 feet of soil, the dimensions of the perchlorate source in groundwater were assumed conservatively to be 120 feet (east-west) by 100 feet (north-south). Because no geologic cross sections were constructed for this site, the geologic cross sections in the neighboring site (LHAAP 35A[58]) were used (Jacobs, 2002a). The thickness of the shallow water-bearing zone, consisting of fine sand, ranged from 2 to 5 feet. Conservatively, a depth of 5 feet was used, as it was assumed that the contaminant source in this shallow zone extended to the entire depth of 5 feet.
- **Distance to Goose Prairie Creek.** Groundwater flows to the east in general but changes locally at LHAAP-04 from time to time. In the current calculation, a distance of 722 feet was used because it is the shortest possible groundwater travel distance from LHAAP-04 to Goose Prairie Creek to the south.
- **Aquifer and Chemical Properties.** The following properties and parameters were the inputs to AT123D model:
 - **Hydraulic conductivity (K):** there is only one test value of $3.5 \times 10^{-5} \text{ cm/sec}$ for LHAAP-04 (Jacobs, 2002a), which is likely not representative of the entire site. Therefore K values tested at LHAAP-35A(58) were included to obtain an average K of $6.36 \times 10^{-4} \text{ cm/sec}$ in this area.
 - **Hydraulic gradient:** 0.0072 feet/feet (based on potentiometric surface map in **Figure 3B**)
 - **Effective porosity:** assumed $0.25\alpha_x = \text{longitudinal groundwater dispersivity (feet)} = x \times 0.1$ (ASTM, 1995 — Table 3.1) where x is the travel distance of contaminants, i.e., 722 feet from the source to the Goose Prairie Creek.
 - $\alpha_y = \text{transverse groundwater dispersivity (feet)} = \alpha_x / 3$ (ASTM, 1995 — Table x3.1).
 - $\alpha_z = \text{vertical groundwater dispersivity (feet)} = \alpha_x / 20$ (ASTM, 1995 — Table x3.1).
 - Retardation factor and degradation were not considered.

2.2.2 Modeling Results and Dilution Factors

The simulation time step was one year with a total simulation period of 100 years and 500 years for the 10-year and 100-year continuous-source scenarios, respectively. These simulation time periods were long enough to capture the maximum concentrations of perchlorate occurring at the point of entry (POE) where groundwater discharges into Goose Prairie Creek. Computer simulation results were evaluated at the POE. These results include the time when perchlorate reaches the POE, the time the concentration reaches its peak, the maximum concentration at this location, the DF and the MSC based on DF and the action level. **Table 2** presents a summary of these results for the 10-year and 100-year continuous source scenarios.

The simulated maximum concentration of perchlorate in groundwater at the POE at Goose Prairie Creek for the 10-year Continuous Source Release Scenario is 3,604 µg/L, which occurs after 56 years (**Table 2** and **Figure 8**). This value is much higher than the perchlorate IAL of 4 µg/L by 901 times. The DF calculated for this scenario at the POE is 21.1 (**Table 2**).

For the 100-year continuous-source release scenario, the simulated maximum concentration of perchlorate in groundwater before discharging into Goose Prairie Creek is 9,650 µg/L, occurring after 125 years (**Table 2** and **Figure 9**). This value is much higher than the IAL of 4 µg/L by 2,413 times. The dilution factors (DF) calculated for this scenario at the POE is only 8.1 (**Table 2**).

Field Confirmation

Additional calculations were conducted to simulate perchlorate concentrations at a well located in a transverse direction from the centerline of the flow. These calculations were conducted to compare the model results with actual field observations.

Based on the above modeling effort, the simulated maximum concentration of perchlorate at the most downgradient monitoring well, 04WW001, is 3,221 µg/L and 7,367 µg/L after 27 years and 100 years for the 10-year and 100-year continuous sources, respectively. This location is approximately 180 feet downgradient from the source area and 100 feet in the transverse direction away from the centerline of the flow. However, the observed concentration, at this location was 3.98 µg/L in 2003 and non-detect in 2005 (Shaw, 2005). Obviously the simulation results are highly elevated and therefore very conservative. As discussed in Section 2.2.3, even with these high concentrations the mixing or dilution concentrations in the creek would still be below the perchlorate IAL, hence protective of surface water.

2.2.3 Dilution in Goose Prairie Creek

Perchlorate in groundwater is subject to mixing and dilution after it is discharged into Goose Prairie Creek.

The DF of perchlorate after mixing with surface water in Goose Prairie Creek is calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW} + Q_{CC}}{Q_{GW}} \quad \text{Equation A6}$$

where Q_{CC} and Q_{GW} are the flow rates in Goose Prairie Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} * \delta_p * L_m \quad \text{Equation A7}$$

where U_{gw} , δ_p and L_m are the approaching groundwater seepage velocity, the thickness and width of the plume approaching surface water. U_{gw} ($= Ki/n$) is 18.95 ft/year, calculated based on the hydraulic conductivity of 6.36×10^{-4} cm/sec, hydraulic gradient of 0.0072 and the effective porosity of 0.25. δ_p is 5 ft and L_m is unknown at the intersection but can be conservatively assumed as the width at the source, which is 120 ft (east-west direction). Then:

$$Q_{GW} = 18.95 / (365 \times 86400) \times 5 \times 120 = 3.6 \times 10^{-4} \text{ ft}^3/\text{s} \quad \text{Equation A8}$$

Calculation of Q_{CC} must be based on the 7Q2 stream flow analysis. The 7Q2 is the low flow at the point of interest, defined as the flow discharge in seven consecutive days that occurs once every two years, statistically. At Goose Prairie Creek, two sets of stream data at the upstream and downstream cross sections are available from the U.S. Army Corps of Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained only during the period of December 1999 to March 2000; a total of only 4 months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period were calculated and presented in **Table 3**. Note that because there is no observation at the point where contaminated groundwater flow discharges into the Goose Prairie Creek, average values between upstream and downstream flow were used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow should be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 2.5 cubic feet per second (cfs) is derived (**Figure 10**). Then:

$$DF = (3.6 \times 10^{-4} + 2.5) / (3.6 \times 10^{-4}) = 6945 \quad \text{Equation A9}$$

The mixing concentrations for perchlorate in Goose Prairie Creek are:

$$\text{10-year continuous source release: } 3604 / 6945 = 0.519 \text{ } \mu\text{g/L}$$

$$\text{100-year continuous source release: } 9650 / 6945 = 1.39 \text{ } \mu\text{g/L}$$

These concentrations are all below the perchlorate IAL of 4 $\mu\text{g/L}$. A conclusion can thus be made that the potential high perchlorate concentration at the source area in groundwater is

protective of surface water. Current non-detect levels for perchlorate in the creek substantiates this conclusion. The mixing concentrations and the overall MSCs for perchlorate are presented in **Table 2.**

3.0 *Soil Concentration Protective of Sediment and Surface Water*

Perchlorate in the subsurface soil, together with the contaminated soil particles will be transported by storm-generated runoff to a nearby stream – in this case Goose Prairie Creek. The approach to develop surface soil concentrations protective of sediment and surface water is described in the main part of this document and the following sections. The distance for the eroded contaminated soil to travel to the nearest stream – Goose Prairie Creek, is 722 feet.

3.1 *Perchlorate Concentration in Erodable Soil Protective of Sediment*

A screening calculation was performed to evaluate whether storm water from an affected property has the potential to pose a risk to human or ecological receptors in the Goose Prairie Creek. First, soil loss from the effected property was evaluated by the revised universal soil loss equation (RUSLE) before soil concentration protective of sediment could be calculated.

3.1.1 *Soil Loss Calculation*

The RUSLE is in the form:

$$A = R * K * L * S * C * P \quad \text{Equation A10}$$

where :

- A* = Estimated average annual soil loss (ton/ac-yr)
- R* = Rainfall-runoff erosivity factor (ft-ton-in/ac-hr-yr)
- K* = Soil erodibility (ton/ac per unit of *R*)
- L* = Slope length factor (unitless)
- S* = Slope steepness factor (unitless)
- C* = Cover management factor (unitless)
- P* = Support practice factor (unitless)

A software, RUSLE, developed by the Agricultural Research Service and the Natural Resource Conservation Service was used to facilitate the input of the parameters and calculation. The input parameters depend on the location of the site being evaluated. The location factor actually implicitly describes rainfall, land use, surface coverage, soil type, and other factors at that location. Since LHAAP is close to Shreveport, Louisiana, some of the parameters established for Shreveport were used for LHAAP as described below.

- **Rainfall-runoff erosivity factor (*R*).** When the factors other than rainfall are held constant, soil losses from cultivated land are directly proportional to a rainstorm parameter: total storm energy (*E*) multiplied by the maximum 30-minute intensity (*I*). *R* was obtained using isoerodent map (Figure 4-1, main document) covering the entire

United States, with R contours available from USDA and USEPA. As discussed in **Section 4.2.1.1**, an R value of 400 is obtained for Shreveport, Louisiana.

- **Soil erodibility (K).** The K factor is the ease with which soil is detached by splash during rainfall, or by surface flow or by a combination of both. It is a function of the composition of soil type, percentage of organic matter, soil structure and grain size, and soil permeability. In this evaluation, it was assumed that the topsoil consists of 29 percent silt and very fine sand, 70 percent clay, 1 percent organic matter, medium to coarse granular (less than 5 mm), and low permeability. The result of K factor using these soil properties in a nomograph is 0.192 as shown in **Tables 4 and 5**, which are soil loss and sediment yield computation worksheets.
- **Topographic factor, including L and S (LS).** The value of LS increases as hillslope length and steepness increase.
 - In this calculation, only one single segment of slope was assumed. Soil texture and land use were assumed as silty clay and “disturbed topsoil, rock cover.” “Rock cover” was assumed to represent pavement and construction with impervious cover. The length of slope was assumed to be 100 feet and 722 feet for the affected area and the total area, respectively. The calculated LS values are 0.04 and 0.14 for the affected area and the total area, respectively, as shown in **Tables 4 and 5**.
- **Cover management factor (C).** The C factor is the ratio of soil loss with specific cropping and management practices to the corresponding loss with up-slope and down-slope tillage and continuously fallow conditions. The calculated values of C are 0.17 (affected area) and 0.119 (total area) as shown in **Tables 4 and 5**.
- **Support practice factor (P).** The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing on soil loss at a particular site. The P factor was calculated through the RUSLE equations and the results are 0.82 and 0.98 respectively for the affected area and the total area as shown in **Tables 4 and 5**.

The resultant soil losses calculated using the RUSLE program are 0.44 tons/ac-yr for the affected area and 1.2 tons/ac-yr for the total area.

In the process of moving towards the outlet, soil will be trapped by vegetation and plant residue or deposited in low lying areas, local scour, rills, and channels. Other factors that inhibit the eroded material's delivery to the watershed outlet include climate, soil particle size and texture, size and proximity of the upland erosion source, the ratio of rill versus sheet erosion, total watershed area, watershed length and relief, and drainage density. Therefore, not all of the soil loss calculated by the above approach will reach the watershed outlet. The sediment yield or load at the outlet should be estimated using a sediment delivery ratio (SDR) from 0 to 1 to account for the above-mentioned deduction factors. RUSLE is designed in calculating the SDR by assigning different values for permanent barriers (strips or concaves) and terraces or sediment basins that

include the land slope, soil type and texture, etc. Because many of the site-specific data are not available, assumptions were made similar to the assumptions described in the previous sections. The SDR values estimated using RUSLE are 0.79 (affected area) and 0.92 (total area) as shown in **Tables 4 and 5**.

The annual sediment yields calculated using RUSLE are 0.42 tons/ac-yr for the affected area and 1.2 tons/ac-yr for the total area (**Tables 4 and 5**).

3.1.2 Calculate ^{Sed}Soil MSC

The soil concentration protective of sediment, ^{Sed}Soil MSC (or C_{AP}), is calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} * C_{TOT}) - (SL_{OA} * C_{OA})}{SL_{AP}} \quad (\text{in mg/kg}) \quad \text{Equation A11}$$

where:

- C_{AP} = the ^{Sed}Soil MSC (mg/kg) for the surface water runoff pathway from the affected area
- SL_{TOT} = total sediment load estimated for the entire contributing watershed. (1.2 metric tons/ac-yr = 1200 kg/ac-yr, see **Section 3.1.1**).
- C_{TOT} = published regulatory standard for sediment (mg/kg)
- SL_{OA} = sediment load (kg/yr) estimated for other areas of the watershed
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds. Because there is no Texas-specific median background soil concentrations, $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area
- SL_{AP} = sediment load from the affected property (in kg/yr). In this case, = 0.42 ton/ac-yr = 420 kg/ac-yr.

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} * C_{TOT})}{SL_{AP}} \quad \text{Equation A12}$$

where:

- $SL_{TOT} = 1200 \text{ kg/ac-yr}$
- $SL_{AP} = 420 \text{ kg/ac-yr}$
- $C_{TOT} = 25 \text{ mg/kg}$ (TCEQ sediment PCL for perchlorate for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002)

Therefore,

$$C_{AP} (^{\text{Sed}}\text{Soil MSC}) = (1200)(25)/420 = 71.4 \text{ mg/kg.} \quad \text{Equation A13}$$

Note that perchlorate concentration in soil at the source that can be eroded is 163 mg/kg which is greater than ^{Sed}Soil MSC (= 71.4 mg/kg).

3.2 Perchlorate Concentration in Erovable Soil Protective of Surface Water

In this study, it was assumed conservatively that TCEQ 7Q2 conditions in Goose Prairie Creek prevail and therefore posed a greater effect on the creek after mixing and dilution.

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D * C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation A14}$$

where:

- C_{AP} = concentration of perchlorate in runoff from the affected property (mg/L)
- Q_D = flow downstream of the affected property watershed (ft³/sec), using 7Q2 flow
- C_D = concentration of perchlorate downstream of the affected property (mg/L)
- Q_{AP} = runoff from the affected property (ft³/sec)
- Q_{OA} = runoff from other areas of the affected property watershed (ft³/sec)
- C_{OA} = concentration of perchlorate in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 * I_U) \quad \text{Equation A15}$$

where:

- R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
- I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated using the following equation:

$$Q = P * P_J * R_{VU} * A_U \text{ (in ft}^3\text{/sec)} \quad \text{Equation A16}$$

where:

- P = precipitation rate (inches/year)
- P_J = ratio of storms producing runoff (unit less) with a default value of 0.9
- R_{VU} = runoff coefficient (unit less) for land use type U (inches_{run}/inches_{rain})
- A_U = area of land use type u (acres)

At LHAAP-04, the affected property was estimated to be 0.28 acres. The annual precipitation at LHAAP was estimated to be 45 inches/year read from the “Water Atlas of the United States” (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 50 % and 10 %, respectively. Therefore,

For the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.5)](0.28)\} = 0.63 \text{ ft}^3/\text{sec} \quad \text{Equation A17}$$

Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and therefore the other areas of the affected property watershed are omitted.

$$Q_D = 2.5 \text{ ft}^3/\text{sec} \quad (\text{Based on the } 10^{\text{th}} \text{ percentile estimate of 7Q2 flow shown in Figure 10}) \quad \text{Equation A18}$$

Based on the calculation in **Section 2.1.3**, the solute concentration of perchlorate (C_{AP}) is 792 mg/L derived from the soil concentration of 163,000 $\mu\text{g/kg}$.

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.63)(792)/2.5 = 199.6 \text{ mg/L} = 199,600 \text{ } \mu\text{g/L} \quad \text{Equation A19}$$

This concentration ($C_D = 199,600 \text{ } \mu\text{g/L}$) is much greater than the IAL of 4 $\mu\text{g/L}$ for perchlorate in surface water.

When perchlorate concentration downstream of the affected property (C_D) is set equal to the IAL of 4 $\mu\text{g/L}$, the resulting C_{AP} represents the perchlorate concentration protective of the receiving surface water (similar to MSC derived in **Section 2.2.2**). Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (2.5)(4)/0.63 = 15.9 \text{ } \mu\text{g/L} \quad \text{Equation A20}$$

Using the following equation in **Section 2.1.3**, perchlorate concentration in soil (C_{soil}) can be derived by:

$$C_{soil} = \frac{[\phi_w + H\phi_a]C_{AP}}{\rho_b} = [0.35 + (0.0)(0.15)](15.9)/1.7 = 3.27 \text{ } \mu\text{g/kg} \quad \text{Equation A21}$$

Note that the actual perchlorate concentration of 163,000 $\mu\text{g/kg}$ at the source is much greater than the C_{soil} ($=^{SW}Soil_{MSC}$), the soil concentration protective of surface water.

4.0 *Summary and Conclusions*

A maximum perchlorate concentration of 163,000 micrograms per kilogram ($\mu\text{g/kg}$) was detected in soil that can be eroded by rainstorm-generated runoff to the nearest point of Goose Prairie Creek. The perchlorate levels found in soil (163,000 $\mu\text{g/kg}$) exceeded the calculated soil concentrations protective of sediment (71,400 $\mu\text{g/kg}$) and surface water (3.27 $\mu\text{g/kg}$).

Modeling of the leaching of perchlorate from the soil to groundwater indicated that perchlorate levels in groundwater as a result of soil leachate are lower than the calculated levels protective of surface water. Subsequent flow mixing and dilution of groundwater into the surface water of Goose Prairie Creek resulted in concentrations of perchlorate that are below the IAL of 4 $\mu\text{g/L}$. Mixing concentrations of perchlorate in Goose Prairie Creek are at 0.519 and 1.39 $\mu\text{g/L}$ for the 10-year and 100-year continuous source release scenarios, respectively.

5.0 References

References are provided in the main document, Section 8.0.

Table 1
Calculated Dilution Factor for Four Scenarios
Leaching of Perchlorate from Soil, LHAAP-04

Scenario	Converted Source Liquid Concentration (Conc _{source}) (µg/L)	Simulated Maximum Concentration in Groundwater (Conc _{mix}) (µg/L)	Dilution Factor (DF)
1	791,700	35,700	22.2
2	791,700	75,900	10.4
3	791,700	45,000	17.6
4	791,700	78,200	10.1

Abbreviations:

µg/L micrograms per Liter
DF dilution factor

Table 2
Summary of Simulated Perchlorate Maximum Concentrations and MSCs
at Goose Prairie Creek (722 feet Downgradient from Source)
Discharged from Groundwater

Scenario	MCL or Action Level (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Source Concentration in Groundwater (µg/L) ^a	Distance to Central Creek (feet)	Maximum Source Release Rate* (kg/hr)	Years Contaminant Starts to Appear (years)	Maximum Concentration in GW POE at Goose Prairie Creek µg/L (years occurred) (DF)	MSC Based on DF in POE at Goose Prairie Creek (µg/L)	Mixing Concentration after Discharge into Goose Prairie Creek (µg/L)	Overall MSC** after Discharge into Goose Prairie Creek (µg/L)
10-year Continuous Source	4.0	100 x 120	75,900	722	2.450E-04	9.0	3,604 (56 years) (21.1)	84.4	0.519	584,971
100-year Continuous Source	4.0	100 x 120	78,200	722	2.530E-04	9.0	9,650 (125 years) (8.1)	32.4	1.39	225,036

Notes and Abbreviations:

All the sources are continuous and extend across the entire aquifer thickness of 5 feet.

*Continuous source release rate in kg/hr = maximum source concentration x recharge rate x source area

**Overall MSC =(maximum source concentration in groundwater / mixing concentration in GPC) x (4.0 µg/L)

a see Table 1 - Appendix A

µg/L micrograms per liter

DF dilution/attenuation factor

MCL maximum contaminant level

MSC medium specific concentration

POE point of entry

Table 3
Calculation of Flow Discharge in Goose Prairie Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (feet ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.10830	0.22081	1.44906	4.88410	2.80	4.20	4.0574	20.5132	12.2853
	10 - 16	0.11651	0.30483	0.48774	2.94988	3.21	6.87	1.5656	20.2657	10.916
	17 - 23	0.06315	0.37523	0.45438	2.12994	2.10	8.56	0.9542	18.2323	9.593
	24 - 30	0.06315	0.36534	0.45438	14.99560	2.10	7.88	0.9542	118.1653	59.560
Jan-00	1 - 7	0.02700	0.36224	0.21000	7.10767	1.05	7.98	0.2205	56.7192	28.470
	8 - 14	0.12681	0.44958	0.24389	11.82963	3.45	18.63	0.8414	220.3860	110.614
	15 - 21	0.03749	0.36559	0.03032	11.51831	1.41	8.35	0.0428	96.1779	48.110
	22 - 28	0.06279	0.42399	0.80813	14.08148	2.08	17.56	1.6809	247.2708	124.476
Feb-00	1 - 7	0.09417	0.42572	0.12182	9.59478	2.65	20.51	0.3228	196.7889	98.556
	8 - 14	0.05132	0.37422	0.04973	6.47123	1.75	8.01	0.0870	51.8346	25.961
	15 - 21	0.03763	0.37675	0.04530	0.53829	1.48	9.24	0.0670	4.9738	2.520
Mar-00	22 - 28	0.14625	0.48311	0.35183	1.14280	4.45	20.51	1.5656	23.4388	12.502
	1 - 7	0.10288	0.37274	0.16989	0.50621	2.79	7.95	0.4740	4.0244	2.249
	8 - 14	0.20995	0.58798	0.48053	1.13559	6.10	21.55	2.9312	24.4720	13.702

Notes and Abbreviations:

Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs cubic feet per second

Table 4
RUSLE Calculation Result for LHAAP-04 – Affected Area

	R	K	LS	C	[P	SDR]	A	SY
SITE4TRA	400	0.19	0.04	0.17	0.82	0.788	.44	.42
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes and Abbreviations:

Annual sediment yield: 0.42 tons/ac-yr

A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Table 5
RUSLE Calculation Result for LHAAP-04 – Total Area

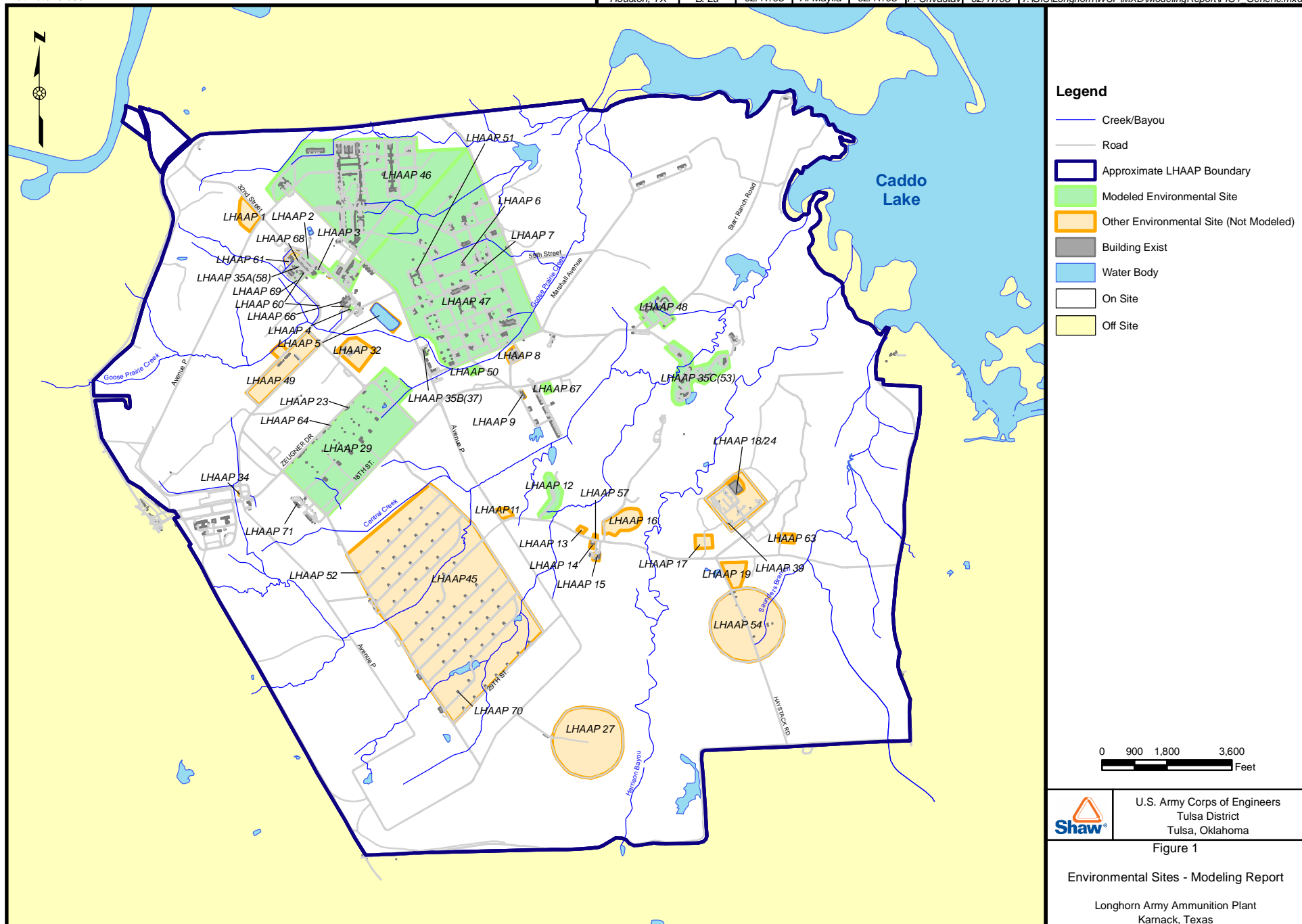
	R	K	LS	C	[P	SDR]	A	SY
SITE4TRA	400	0.19	0.14	0.12	0.98	0.919	1.2	1.2
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes and Abbreviations:

Annual sediment yield: 1.2 tons/ac-yr
A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd

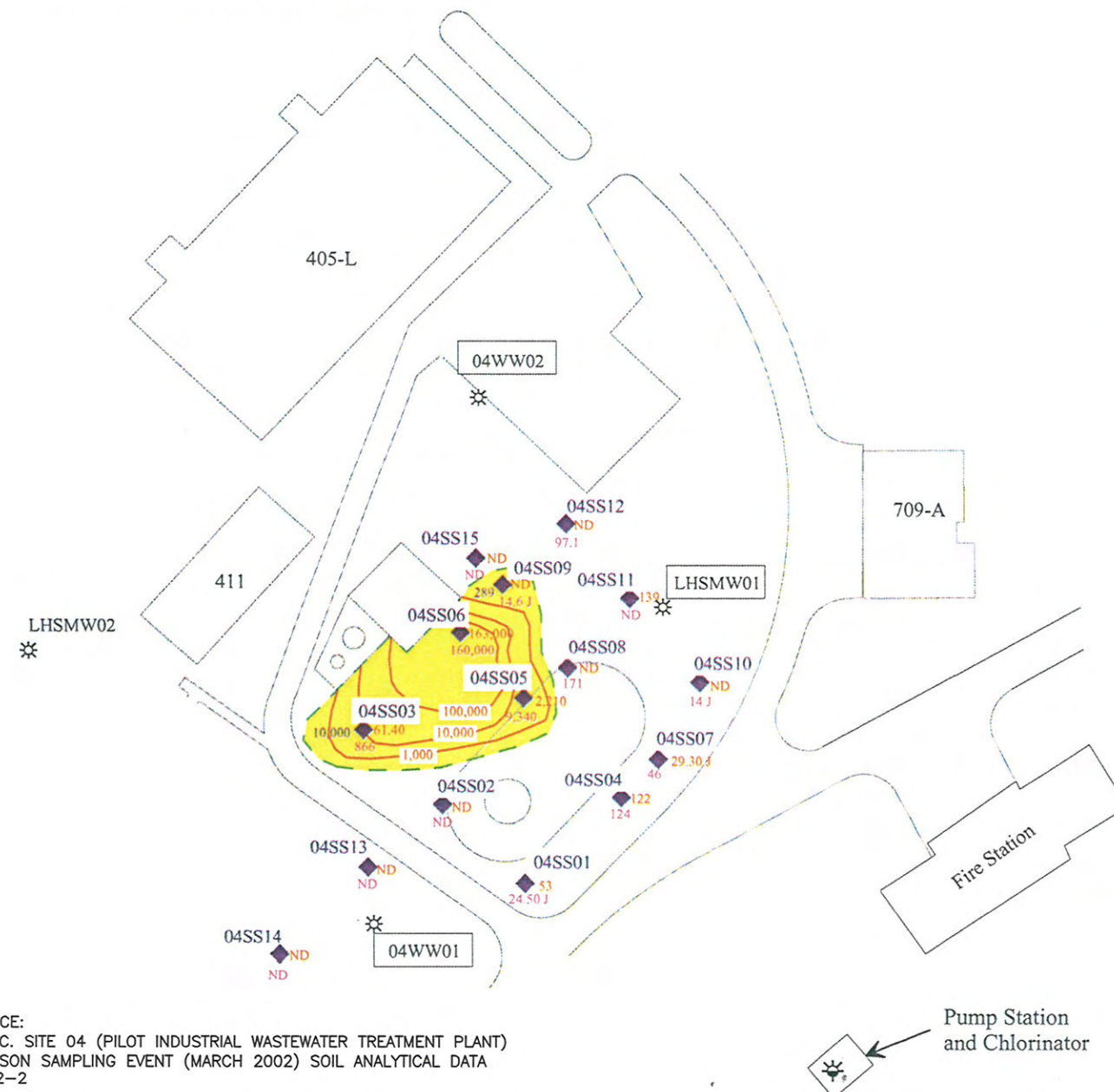


PLOT DATE: 10/11/04
 FORMAT REVISION 5/13/02

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER	845714-A26
---	---	Houston, Texas	D. DAY	10/11/04	K. EVERETT	10/14/04	P. SRIVASTAV	10/14/04		

Note: All soil analytical values are in microgram per kilogram (ug/kg).
 "ND" indicates the sample value was either below the Method Detection Limit
 or was determined by data validation to be a non-detect for Perchlorate.
 "J" values were estimated values as determined by data validation.

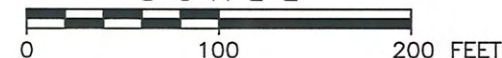
04WW03



LEGEND

- Shallow Zone Monitoring Wells
- Soil sampling points with perchlorate concentrations (ug/kg)
- Approximate Location of Water Supply Well
- Area with concentrations of perchlorate in soil >260 ug/kg
- Order of magnitude contours

SCALE



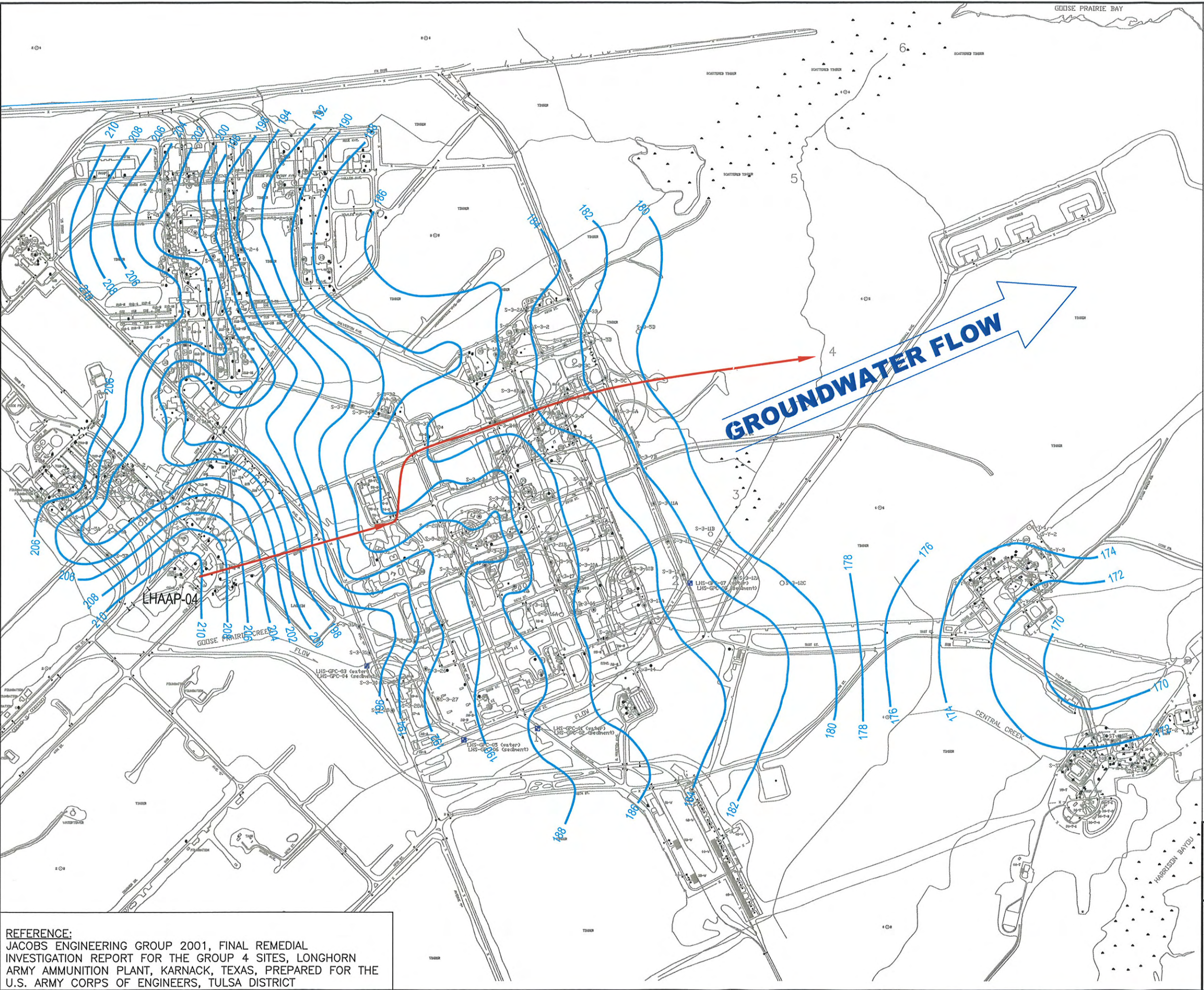
U.S. ARMY CORPS OF ENGINEERS
 TULSA DISTRICT
 TULSA, OKLAHOMA

FIGURE 2 - APPENDIX A
 LHAAP-04 WET SEASON SAMPLING EVENT
 (MARCH 2002) SOIL ANALYTICAL DATA
 LONGHORN ARMY AMMUNITION PLANT
 KARNACK, TEXAS

REFERENCE:
 STEP, INC. SITE 04 (PILOT INDUSTRIAL WASTEWATER TREATMENT PLANT)
 WET SEASON SAMPLING EVENT (MARCH 2002) SOIL ANALYTICAL DATA
 FIGURE 2-2

IMAGE X-REF OFFICE DRAWN BY CHECKED BY APPROVED BY DRAWING NUMBER
--- --- Houston, Texas J. RDZ 10/07/03 K. EVERETT 10/14/04 P. SRIVASTAV 10/14/04 845714-B48

PLOT DATE: 5/6/04
FORMAT REVISION 3/25/99



00043307



LEGEND:

- POTENTIOMETRIC SURFACE CONTOUR (DECEMBER 1998 DATA)
- GROUNDWATER POSSIBLE FLOW PATH



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

FIGURE 3A - APPENDIX A
SHALLOW GROUNDWATER ELEVATION
CONTOUR MAP (DECEMBER 1998 DATA)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

REFERENCE:
JACOBS ENGINEERING GROUP 2001, FINAL REMEDIAL
INVESTIGATION REPORT FOR THE GROUP 4 SITES, LONGHORN
ARMY AMMUNITION PLANT, KARNACK, TEXAS, PREPARED FOR THE
U.S. ARMY CORPS OF ENGINEERS, TULSA DISTRICT

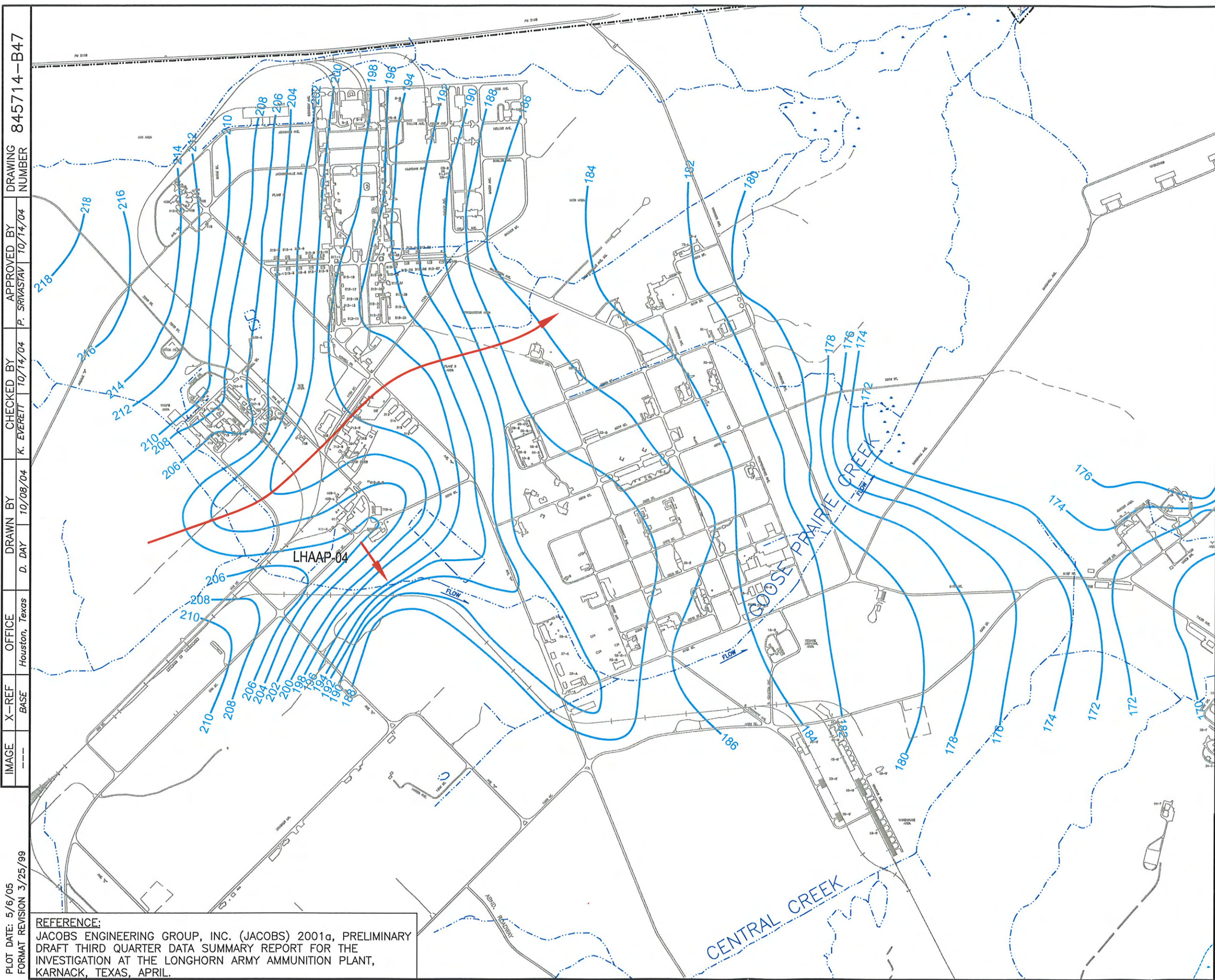


IMAGE X-REF OFFICE DRAWN BY CHECKED BY APPROVED BY
BASE Houston, Texas D. DAY 10/08/04 K. EVERITT 10/14/04 P. SRIVASTAV 10/14/04
DRAWING NUMBER 845714-B47

PLOT DATE: 5/6/05
FORMAT REVISION 3/25/99

LEGEND:

- POTENTIOMETRIC SURFACE CONTOUR
- GROUNDWATER FLOW DIRECTION

SCALE

0 1000 2000 FEET

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

Shaw

FIGURE 3B - APPENDIX A
SHALLOW GROUNDWATER CONTOUR MAP
(SEPTEMBER 2000 DATA)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Figure 4 - Appendix A
Mixing Concentration in Groundwater Contributed
by Soil Leachate Condition at the Source Area
LHAAP-04, Longhorn Army Ammunition Plant, Texas

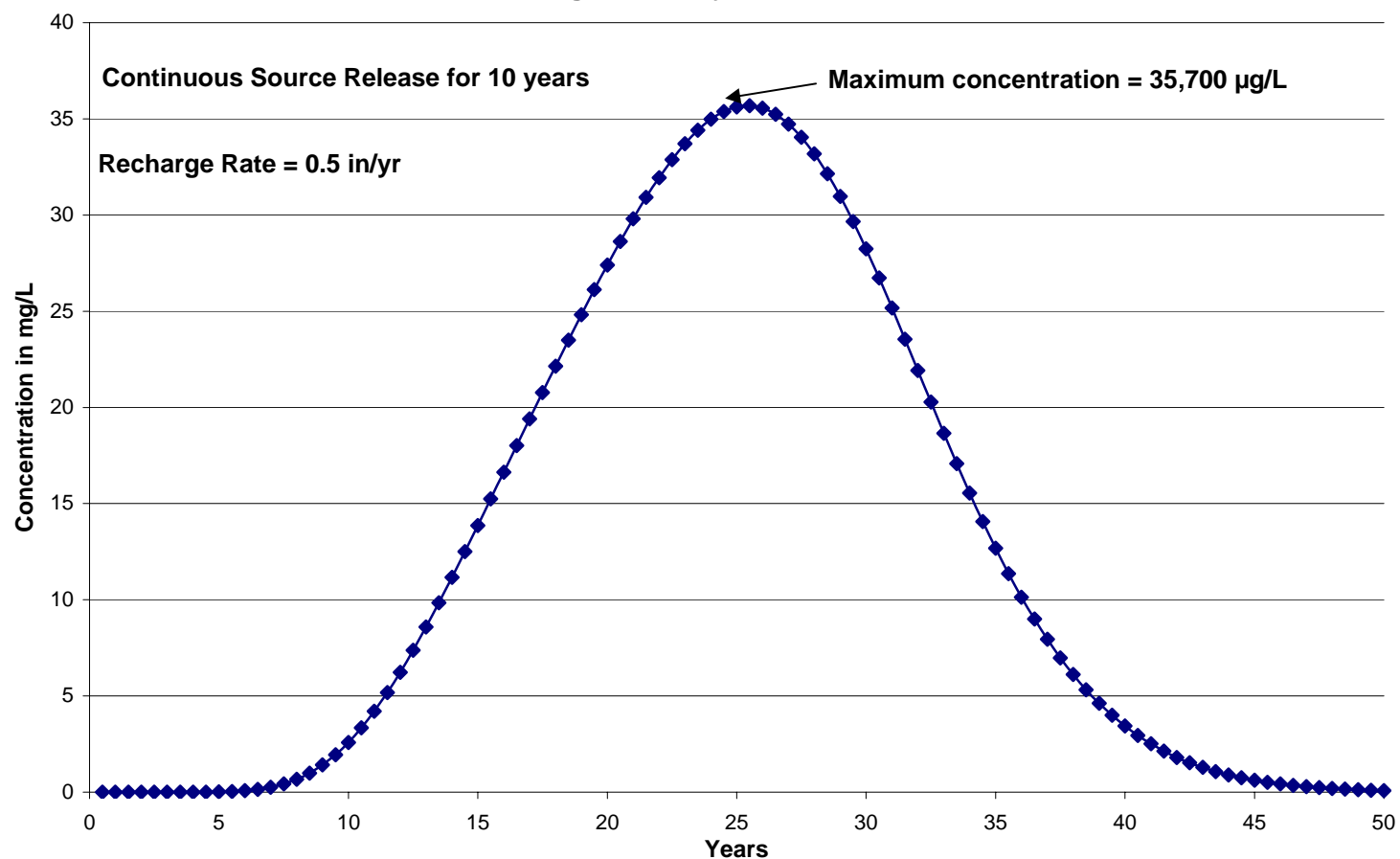


Figure 5 - Appendix A
Mixing Concentration in Groundwater Contributed
by Soil Leachate Condition at the Source Area
LHAAP-04, Longhorn Army Ammunition Plant, Texas

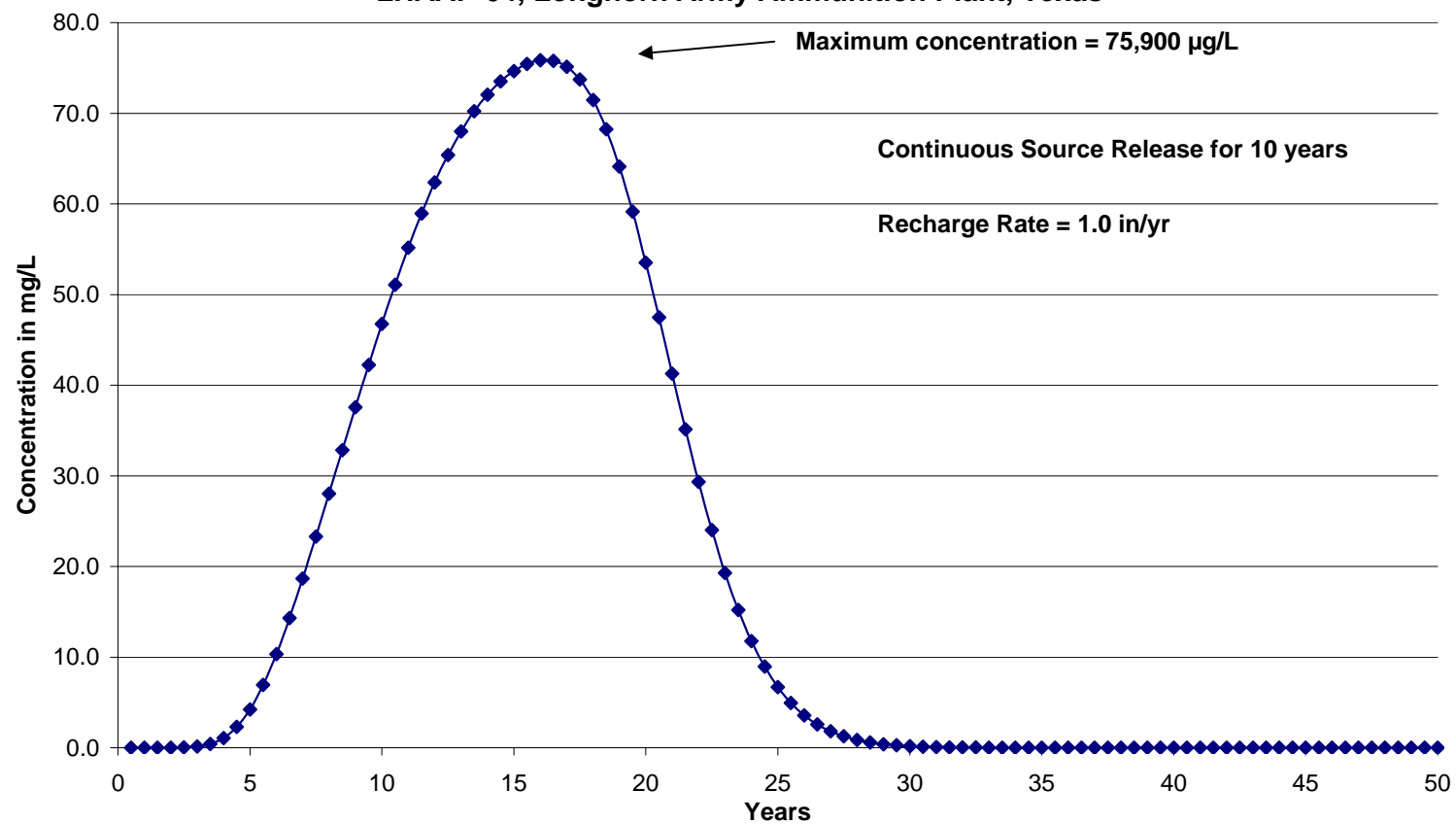


Figure 6 - Appendix A
Mixing Concentration in Groundwater Contributed
by Soil Leachate Condition at the Source Area
LHAAP-04, Longhorn Army Ammunition Plant, Texas

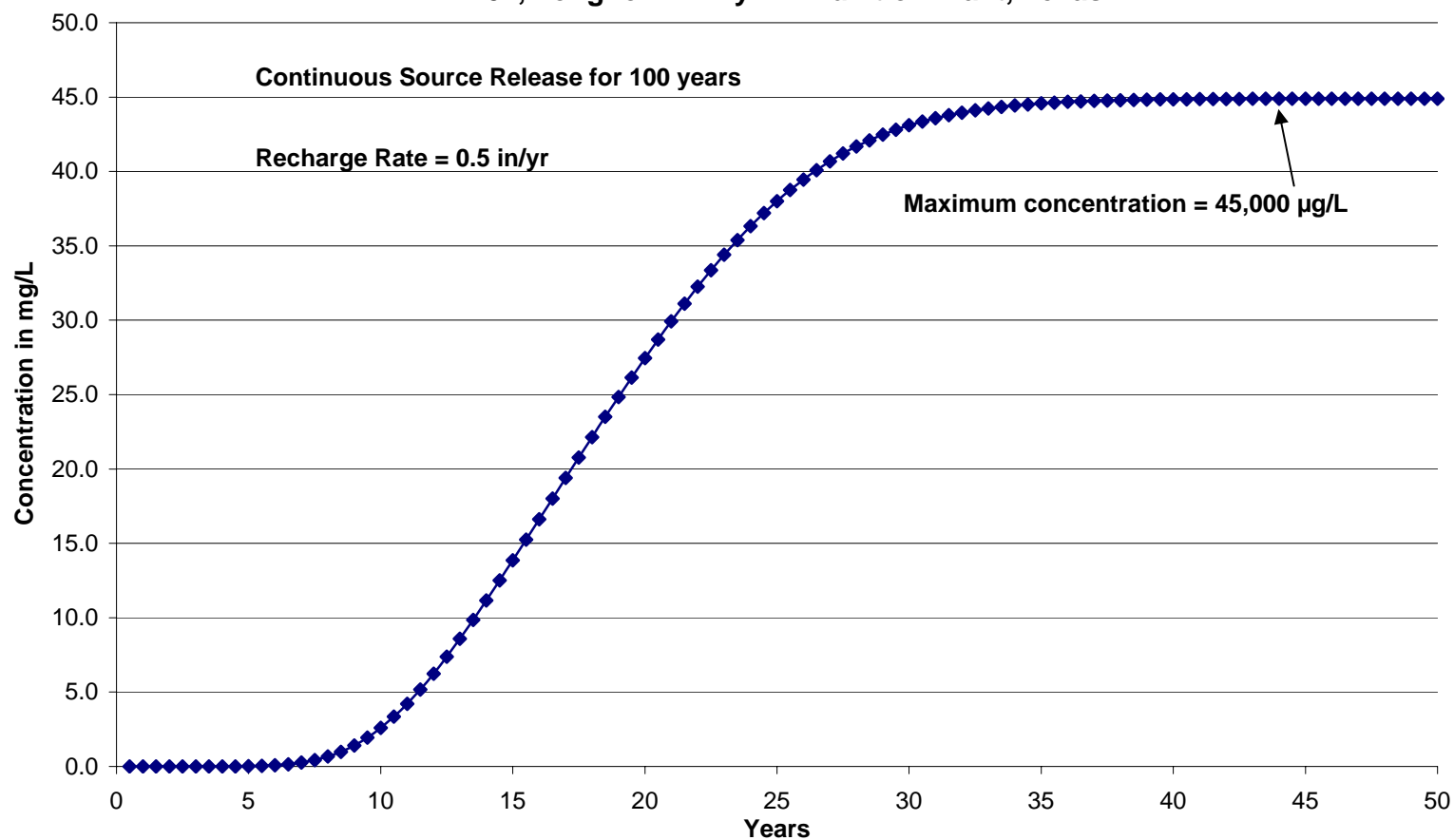


Figure 7 - Appendix A
Mixing Concentration in Groundwater Contributed
by Soil Leachate Condition at the Source Area
LHAAP-04, Longhorn Army Ammunition Plant, Texas

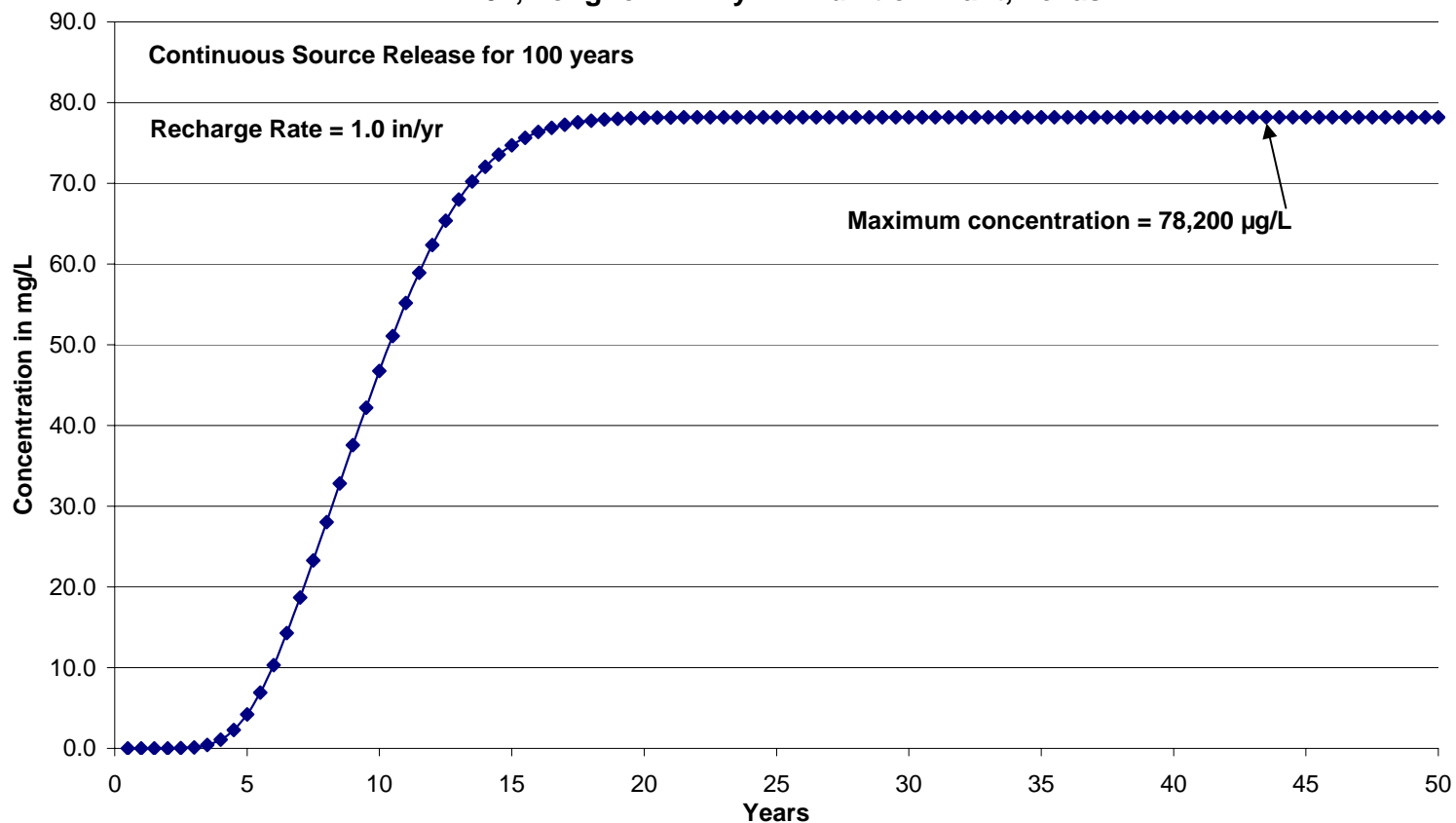


Figure 8 - Appendix A
Perchlorate Concentrations in Groundwater Contributed
by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek
(722 feet from Source)
Site 4, Longhorn Army Ammunition Plant, Texas

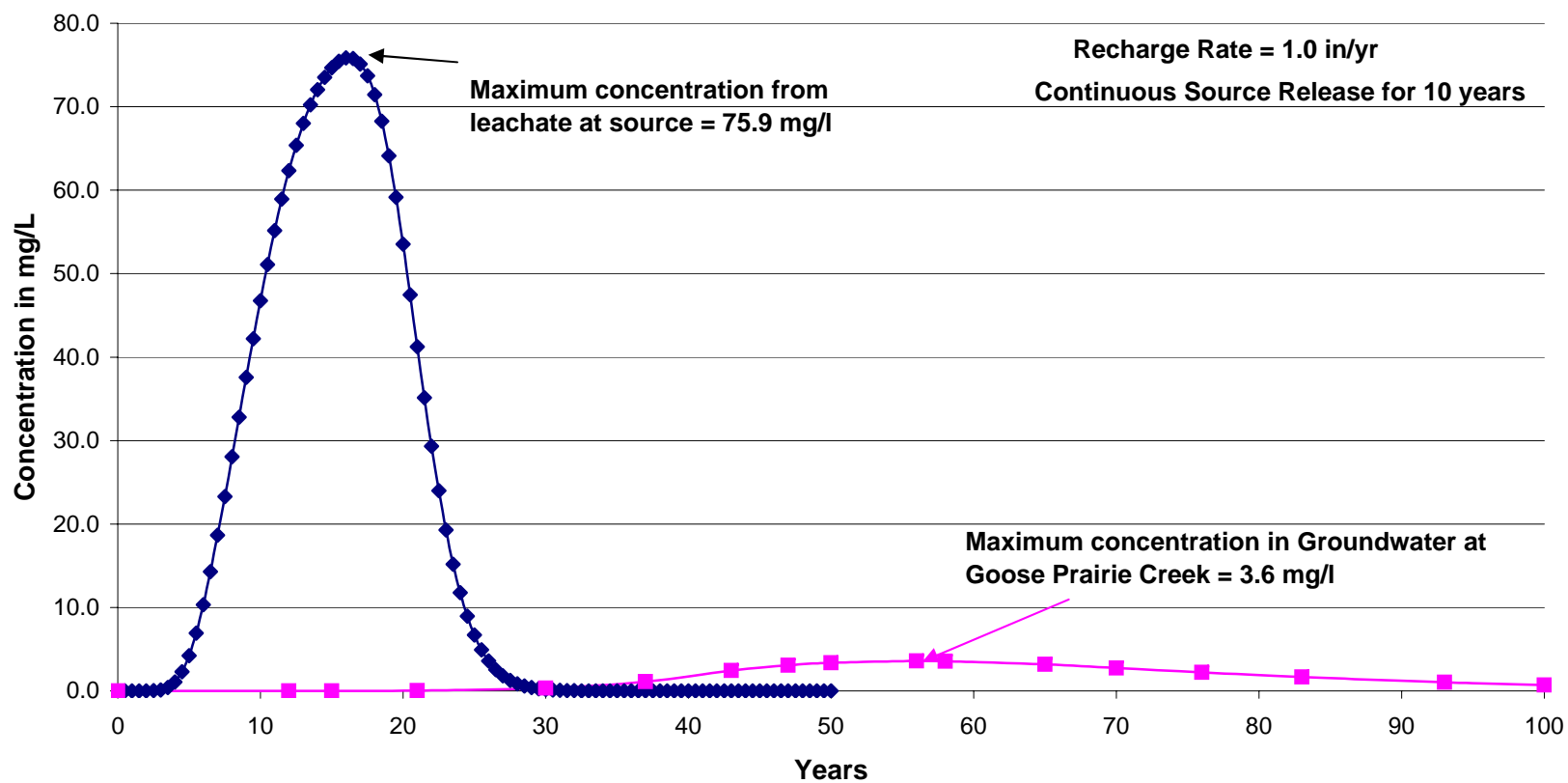


Figure 9 - Appendix A
Perchlorate Concentrations in Groundwater Contributed
by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek
(722 Feet From Source)
Site 4, Longhorn Army Ammunition Plant, Texas

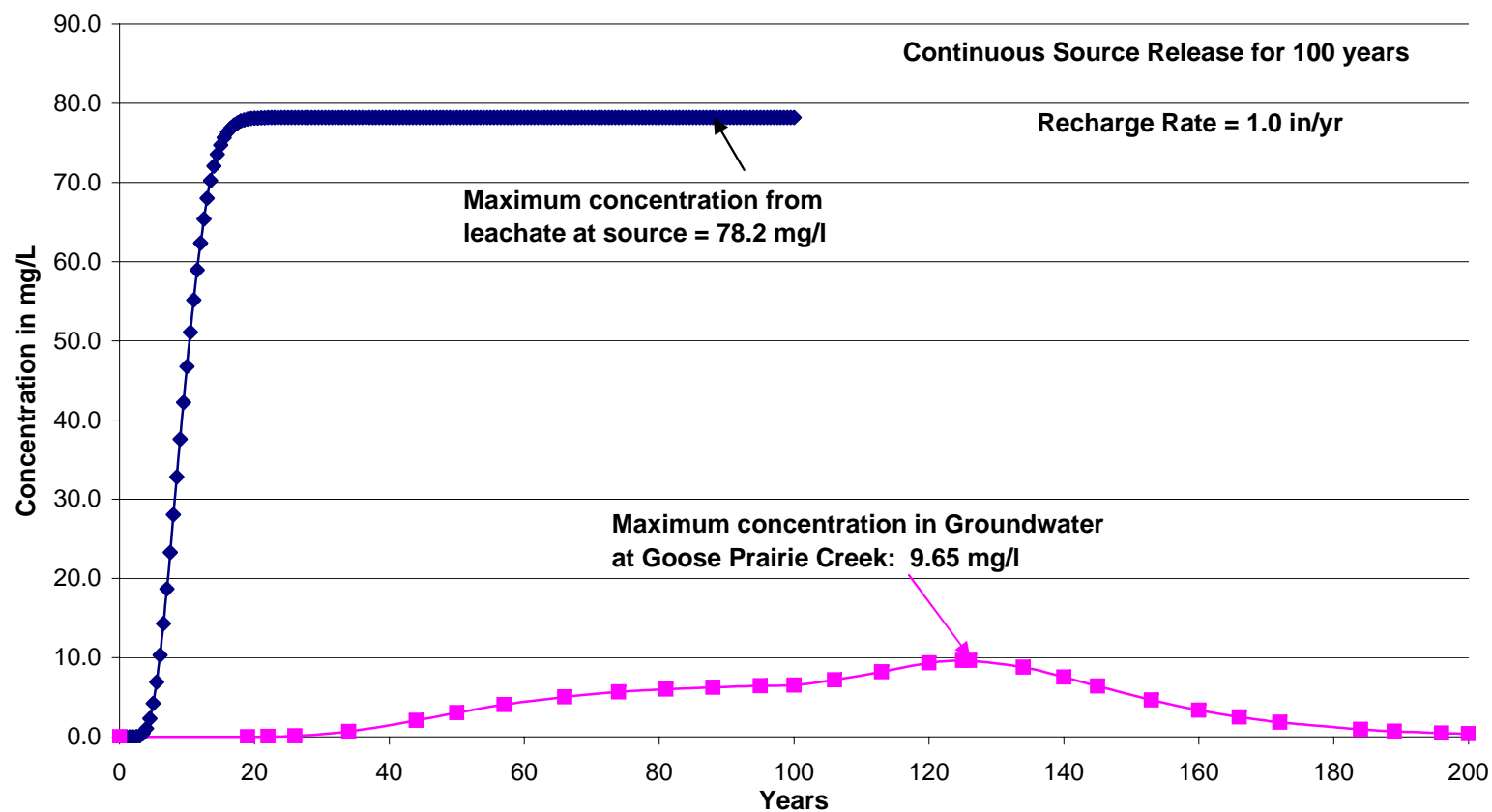
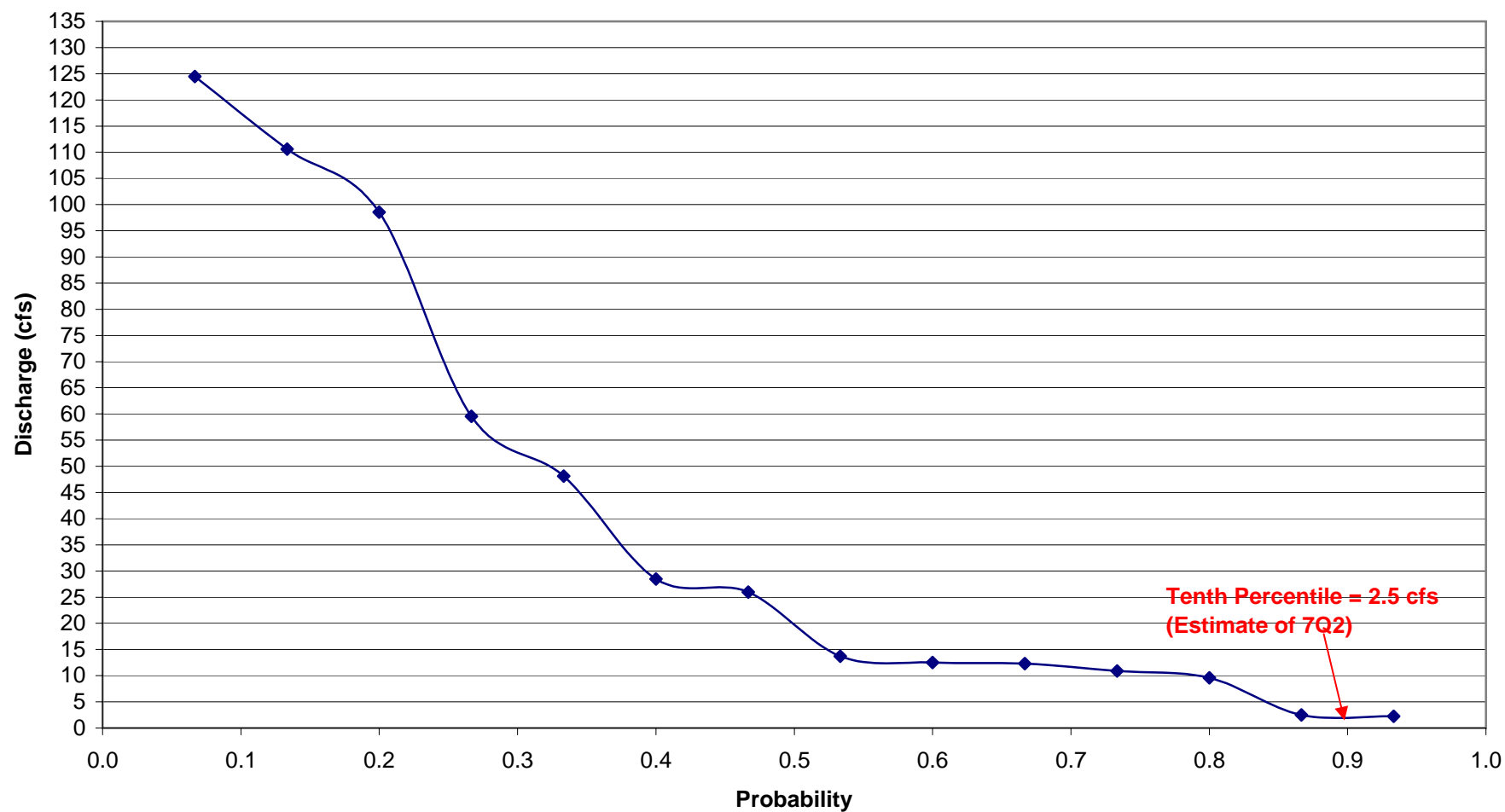


Figure 10 - Appendix A
7Q2 Low Flow Analysis
Probability vs Flow Discharge for Goose Prairie Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix B

LHAAP-12 Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek

Table of Contents

1.0	Introduction	1-1
2.0	Modeling	2-1
3.0	Calculation Results	3-1
4.0	Dilution Factors for TCE and Perchlorate Evaluated at the Point of Discharge into Central Creek	4-1
5.0	Summary and Conclusions	5-1
6.0	References	6-1

List of Tables

Table 1	Calculation of Dilution Factor (DF) using Domenico's Equation (Trichloroethene)
Table 2	Calculation of Dilution Factor (DF) using Domenico's Equation (Vinyl Chloride)
Table 3	Calculation of Dilution Factor (DF) using Domenico's Equation (Perchlorate)
Table 4	Calculation of Flow Discharge in Central Creek
Table 5	Summary of Derivation of Dilution Factors and Medium-Specific Concentrations (MSCs)

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Groundwater Potentiometric Surface in the Shallow Permeable Zone Based on August 25, 2003, Water Level Measurements – Modeling Report
Figure 3	7Q2 Low Flow Analysis, Probability vs Flow Discharge for Central Creek, Based on December 1999 to March 2000 Flow Derivation

1.0 Introduction

LHAAP-12 is located approximately at the center of Longhorn Army Ammunition Plant (LHAAP) with LHAAP-67 to the north and LHAAP-16 to the southeast (**Figure 1**).

The chemicals of concern (COC) at LHAAP-12 are trichloroethene (TCE), vinyl chloride (VC), and perchlorate. These three compounds were detected at maximum concentrations of 495 µg/L, 2.1 µg/L, and 56 µg/L, respectively in the groundwater. The purpose of the following calculation is to determine the dilution factor of each contaminant at the location where it may enter the nearest surface body.

There are two nearby streams, Central Creek and Harrison Bayou where groundwater from LHAAP-12 is likely to be discharged. During the dry season (September 2002), groundwater elevations at LHAAP-12 varied from 180.86 to 181.94 feet above sea level (msl) and during the wet season (March 2002) from 180.56 to 184.92 feet msl. Recent creek survey data indicated that the bottom of Central Creek is at elevations of 182.01 and 181.9 feet for location CC-1 and 183.41 and 182.92 feet for location CC-2. Streambed survey data indicate that groundwater underlying LHAAP-12 is at a lower elevation than Central Creek during the dry season and may not discharge into the creek. However, groundwater may potentially discharge to Central creek during the wet season. A table presenting groundwater and Central Creek surface water elevations is included in Appendix M.

The elevation of the edge of the swamp for Harrison Bayou was measured at 167.85 and 166.73 feet above msl. Harrison Bayou is at a lower elevation than groundwater underlying the site. Therefore, groundwater will discharge to Harrison Bayou.

Although groundwater is likely to discharge to Harrison Bayou than to Central Creek, but because Central Creek is closer to LHAAP-12, for conservative calculation purposes and assuming the worst-case scenario, it was assumed that groundwater discharges to Central Creek.

At LHAAP-12, the shallow groundwater potentiometric map (August, 2003) indicated that groundwater is flowing toward the northeast for the majority of the site and flowing north at the north end of the site (**Figure 2**). Groundwater flowing to the north could enter Central Creek at a distance of 588 feet from the north end of LHAAP-12.

The purpose of this calculation is to estimate the dilution factors (DFs) for the three COCs at the interface of groundwater and Central Creek and to develop the groundwater medium-specific concentrations (MSCs) by multiplying these dilution factors with the maximum contaminant levels (MCLs) or action levels.

2.0 Modeling

The dilution factors of the COCs were obtained using the Domenico equation (Domenico and Schwartz, 1998) based on the possible flowpath mentioned above and the various parameters described in the following sections.

The Domenico equation is expressed as follows:

Equation B1

$$DF = \frac{C_{si}}{C_{(x)i}} = \left\{ \exp \left[\frac{x}{2\alpha_x} \left(1 - \sqrt{1 + \frac{4\lambda_i \alpha_x R_i}{v}} \right) \right] \left(\operatorname{erf} \left[\frac{S_w}{4\sqrt{\alpha_y x}} \right] \right) \left(\operatorname{erf} \left[\frac{S_d}{2\sqrt{\alpha_z x}} \right] \right) \right\}^{-1}$$

The notations in this equation and the related equations as well as the value for each variable are explained below. Note that some assumptions are made.

DF = dilution factor.

C_{si} = concentration of constituent i in source zone ($\mu\text{g/L}$).

$C_{(x)i}$ = concentration of constituent i in groundwater at distance x downgradient of source ($\mu\text{g/L}$).

S_w = source width perpendicular to groundwater flow (feet). Average length of landfill perpendicular to groundwater flow = 150 feet (Figure 2-1—Jacobs, 2002c).

S_d = source thickness (i.e., the thickness of the affected groundwater within the permeable zone) (feet). Since the thickness of the contaminated plume is unknown, the average thickness of the water bearing zone was used. The thickness of the shallow permeable zone at LHAAP-12 is in the range of 5 to 20 feet, the average thickness of the permeable water bearing zone (sand) = 12.5 feet (Jacobs, 2001b).

D_v = groundwater Darcy velocity in feet/yr ($= Ki$).

Where:

K = is the hydraulic conductivity, which is in the range of 3.50×10^{-7} cm/sec to 4.54×10^{-3} cm/sec (Table 3-2—Jacobs, 2001b). By eliminating the extreme low value of 3.50×10^{-7} cm/sec, the average K value is 781.1 feet/year.

i = the hydraulic gradient.
= difference of head/distance.

Based on the potentiometric surface contour map (**Figure 2**)

$$i = 0.016.$$

$$v = \text{groundwater seepage velocity in feet/yr } (= D_v/n), \text{ where } n \text{ is the effective porosity, assumed } 0.25.$$

$$x = \text{distance downgradient from source} \\ = 588.2 \text{ feet is the shortest distance from source to Central Creek based on} \\ \textbf{Figure 1.}$$

$$\lambda_i = \text{first-order degradation rate for constituent } i \text{ (day}^{-1}\text{)}.$$

$$\lambda_i = \frac{\ln 2}{(t_{1/2})_i}$$

Where:

$$\ln 2 = \text{natural log of } 2$$

$$(t_{1/2})_i = \text{the half-life of constituent } i.$$

Because no site-specific degradation rate was tested, conservative literature half-life values were used (Howard et al., 1991):

For TCE

$$t_{1/2} = 4.5 \text{ years (maximum)}$$

$$\lambda_{tce} = 0.154 \text{ (1/yr)}$$

For VC

$$t_{1/2} = 8.0 \text{ years (maximum)}$$

$$\lambda_{vc} = 0.087 \text{ (1/yr)}$$

Perchlorate

Because perchlorate is kinetically nonlabile (i.e., the reduction of the central chlorine atom occurs extremely slowly) and sorption or natural chemical reduction in the environment is not significant, perchlorate is exceedingly mobile in aqueous systems and can persist for many decades under typical groundwater and surface water conditions (USEPA, 2002). Because of this, the degradation rate for perchlorate was assumed to be zero.

$$R_i = \text{retardation factor for constituent } i \text{ (dimensionless).}$$

$$R_i = [1 + (K_d \rho_b / n)]$$

Equation B2

Where:

$$K_d \text{ (cm}^3\text{/g)} = \text{the distribution coefficient for that constituent}$$

$$\rho_b = \text{the dry soil bulk density in g/cm}^3.$$

$$K_d = K_{oc} f_o$$

Where:

K_{oc} = the carbon-water sorption coefficient (cm^3/g) and the average values based on literature values are (Montgomery, 2000) TCE at $100 \text{ cm}^3/\text{g}$ and VC at $2.45 \text{ cm}^3/\text{g}$.

Perchlorate is an inorganic compound; however, there is some sorption for perchlorate at a negligible value. for the reason mentioned above, it was assumed that there was no retardation for the movement of perchlorate.

foc is the fraction of organic carbon content. Assume 0.1 percent for sand at the site.

α_x = longitudinal groundwater dispersivity (feet) ($= x \cdot 0.1$) (ASTM, E-1739-95, Table x3.1, 1995)

α_y = transverse groundwater dispersivity (feet) ($\alpha_x / 3$) (ASTM, E-1739-95, Table x3.1, 1995)

α_z = vertical groundwater dispersivity (feet) ($\alpha_x / 20$) (ASTM, E-1739-95, Table x3.1, 1995)

erf = error function

$$erf\chi = \frac{2}{\sqrt{\pi}} \int_0^{\chi} e^{-t^2} dt$$

Equation B3

S_d is a site specific variable. However, it can be determined by adding the depth caused by advection and the depth caused by vertical dispersion:

$$S_d = h_{adv} + h_{disp}$$

Where:

h_{adv} = the advective component of the plume depth (feet):

$$h_{adv} = B\{1 - \exp[(-I \cdot L)/(B \cdot D_v)]\}$$

Equation B4

Where:

B = the aquifer thickness (feet)

I = the infiltration rate (feet/year, assuming 2 inch/year, i.e., 0.042 feet/year)

L = the source length parallel to groundwater flow which is 350 feet (Figure 2-1—Jacobs, 2002c).

h_{disp} = the dispersive component of the plume depth

$$h_{disp} = (2 \cdot \alpha_z \cdot L)^{1/2}$$

If the calculated S_d exceeds the thickness of the aquifer, then $S_d = B$.

The thickness of the affected permeable zone shall be used as S_d if the thickness of the groundwater plume is unknown. Therefore in the current case, $S_d = B$.

3.0 Calculation Results

The calculations of the dilution factor for each of the three COCs were performed with a spreadsheet and the results are presented as **Table 1** for TCE, **Table 2** for VC, and **Table 3** for perchlorate. The calculated DFs for TCE, VC, and perchlorate are 30.485, 6.836, and 2.641, respectively, in the groundwater at the point of entry (POE) into Central Creek. The corresponding concentrations at this location for TCE, VC, and perchlorate are 16.23 µg/l, 0.307 µg/L, and 21.2 µg/L, respectively.

The MCLs for TCE and VC are 5 µg/l and 2 µg/l, respectively, and the TCEQ interim action level (IAL) for perchlorate is 4 µg/L.

Based on the calculated DFs calculated at POE into Central Creek, the MSCs for the three COCs are:

TCE: $5 \mu\text{g/L} \times 30.49 = 152.45 \mu\text{g/L}$
(Current maximum concentration at source: 495 µg/L)

VC: $2 \mu\text{g/L} \times 6.836 = 13.67 \mu\text{g/L}$
(Current maximum concentration at source: 2.1 µg/L)

Perchlorate: $4 \mu\text{g/L} \times 2.64 = 10.56 \mu\text{g/L}$
(Current maximum concentration at source: 56 µg/L)

These results show that TCE and perchlorate concentrations at the POE into Central Creek are above their acceptable levels. Therefore, the mixing concentrations of these two contaminants after they discharge into the Central Creek must be calculated.

4.0 Dilution Factors for TCE and Perchlorate Evaluated at the Point of Discharge into Central Creek

The concentrations of TCE and perchlorate ($Conc_{CC}$) at the POE are calculated by dividing the source concentration by the DF calculated above:

For TCE:

$$Conc_{CC} = 495 \text{ } \mu\text{g/l} / 30.49 = 16.23 \text{ } \mu\text{g/L}$$

For perchlorate:

$$Conc_{CC} = 56 \text{ } \mu\text{g/l} / 2.64 = 21.2 \text{ } \mu\text{g/L}$$

The concentrations of TCE and perchlorate after mixing with surface water in Central Creek are calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW}}{Q_{CC} + Q_{GW}} \quad \text{Equation B5}$$

Where:

Q_{CC} and Q_{GW} are the flow rates in Central Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} * \delta_p * L_m \quad \text{Equation B6}$$

Where:

U_{gw} , δ_p , and L_m are the approaching groundwater seepage velocity, the thickness, and the width of the plume approaching surface water, respectively.

U_{gw} ($= Ki/n$) is 49.98 feet/year calculated based on the hydraulic conductivity, hydraulic gradient, and the effective porosity listed in **Tables 1, 2 and 3**.

δ_p is 12.5 feet and L_m is unknown at the intersection but can be conservatively assumed as the width at the source, which is 150 feet. Then:

$$Q_{GW} = 49.98 / (365 \times 86400) \times 12.5 \times 150 = 2.97 \times 10^{-3} \text{ ft}^3/\text{s}.$$

Calculation of Q_{CC} must be based on the 7Q2 stream flow analysis. 7Q2 is the low flow at the POE, defined as the flow discharge in seven consecutive days that occurs once every two years

statistically. At Central Creek, only two sets of stream data at the upstream and downstream cross sections are available from the U.S. Army Corps of Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained during the period of December 1999 to March 2000, a total of only 4 months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period are calculated and presented in **Table 4**. Note that there is no observation at the point where contaminated groundwater flow discharges into the Central Creek; rather, average values between upstream and downstream flow are used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 1.0 cubic feet per second (cfs) is derived (**Figure 3**). Then,

$$DF = (2.97 \times 10^{-3}) / (2.97 \times 10^{-3} + 1.0) = 2.961 \times 10^{-3} \quad \text{Equation B7}$$

The mixing concentrations for TCE and perchlorate in Central Creek are:

For TCE:

$$Conc_{mix} = 2.961 \times 10^{-3} \times 16.23 = 0.05 \mu\text{g/L}$$

The overall DF of TCE at point of discharge into the Central Creek is $495/0.05 = 9,900$. The MSC for TCE is therefore $9,900 \times 5 \mu\text{g/L} = 49,500 \mu\text{g/L}$. Note that the observed concentration at the site, $495 \mu\text{g/L}$, is much lower than the calculated MSC.

For perchlorate:

$$Conc_{mix} = 2.961 \times 10^{-3} \times 21.2 = 0.063 \mu\text{g/L}$$

The overall DF at point of discharge into the Central Creek is $56/0.063 = 892.1$. The MSC for perchlorate is therefore $892.1 \times 4 \mu\text{g/L} = 3,568 \mu\text{g/L}$. Note that the observed concentration at the site, $56 \mu\text{g/L}$, is much lower than the calculated MSC.

5.0 *Summary and Conclusions*

Table 5 summarizes the calculation results in terms of dilution factors and concentrations at different locations with maximum concentrations detected at the source for comparison.

The results of the Domenico equation calculations indicated that at the location where groundwater enters Central Creek, TCE, vinyl chloride, and perchlorate maximum concentrations in groundwater are 16.23, 0.307, and 21.2 $\mu\text{g/L}$, respectively. Even prior to mixing and dilution, vinyl chloride levels are below the MCL of 2 $\mu\text{g/L}$. TCE and perchlorate concentrations decrease substantially with mixing and dilution to 0.03 and 0.038 $\mu\text{g/L}$, respectively; levels that are below the MCL and the action level. The current maximum concentrations at the source (TCE [495 $\mu\text{g/L}$], vinyl chloride [2.1 $\mu\text{g/L}$], and perchlorate [56 $\mu\text{g/L}$]) are lower than the MSCs protective of surface water for all three COCs including TCE (49,500 $\mu\text{g/L}$), perchlorate (3,568 $\mu\text{g/L}$), and vinyl chloride, the concentrations of which are lower than the MSC protective of groundwater at POE even before mixing with surface water in the creek.

Field Confirmation

Note that the calculation of all three constituents using Domenico's equation was based on a distance of 588 feet from the north end of the landfill at LHAAP-12, and there is no monitoring well downgradient and in the lateral direction of the landfill. No calculation was attempted for a lateral location downgradient of the landfill to provide field confirmation of the model.

6.0 References

References are provided in the main document, in Section 8.0.

Table 1
CALCULATION OF DILUTION FACTOR (DF) USING DOMENICO'S EQUATION
(LHAAP-12, Longhorn Army Ammunition Plant, Texas)

(Trichloroethene)
TCE Discharged to Central Creek
(Assumed TCE half-life = 4.5 years [Howard et al., 1991]⁽¹⁾)

L	350 ft
alphaz1	1.75 ft
B	12.5 ft
Dv	12.4976 ft/year
I	0.042 ft/year
Aquifer thickness (H)	12.5 ft

Sw	150 ft	x	588.2 ft
effective n	0.25	alpha x	58.82 ft
lambda	0.154 1/yr	alpha y	19.61 ft
R	1.68	alpha z	2.941 ft
I	0.016 ft/ft	Koc	100 cm ³ /g
K	781.1 ft/yr	foc	0.001
v	49.9904 ft/year	rho	1.7 g/cm ³

Calculations:

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft

Identify the following condition:

$$X_p = (H - S_d)^2 / \alpha_{phz} = 0.0000 \text{ ft}$$

Xp = 0.0 (i.e. Sd = H)

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft
DF DOMENICO	30.485

Parameters Definition, Assumptions and Sources

L	length of source parallel to groundwater flow in feet
alphaz1	vertical dispersivity in feet ($=L/200$) ⁽²⁾
B	thickness of shallow water bearing zone in feet
Dv	Darcy horizontal velocity in ft/yr ($= K \times i$)
I	infiltration rate in ft/yr
Sw	source width perpendicular to groundwater flow in feet
Sd	source thickness in feet (if $hadv + hdisp > B$, $Sd = B$ or else $Sd = hadv + hdisp$) (NOTE: The thickness of the impacted permeable zone shall be used if the thickness of the plume isn't known) $hadv = B[1 - \exp(-I \times L / (B \times Dv))]$ $hdisp = (2 \times \alpha_{phz1} \times L)^{1/2}$
effective n	effective porosity
lambda	first order degradation rate
R	retardation factor ($= 1 + (Kd \times \rho) / n$) where $Kd = Koc \times foc$ (Koc = soil sorption coefficient, assumed nitrate not adsorbed) (foc = fraction of organic carbon in soil = 0.1%, assumed for silty clay) ρ = bulk density = assumed 1.7 g/cm ³
I	hydraulic gradient
K	hydraulic conductivity in ft/yr
v	groundwater seepage velocity in ft/yr ($= K \times i / n$)
x	distance down gradient from source in feet
alpha x	longitudinal groundwater dispersivity in feet ($= 0.1x$) ⁽²⁾
alpha y	transverse groundwater dispersivity in feet ($= \alpha_{phz} / 3$) ⁽²⁾
alpha z	vertical groundwater dispersivity in feet ($= \alpha_{phz} / 20$) ⁽²⁾

Reference:

- (1) Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M., Meylan, and E.M. Michalenko, 1991, "Environmental Degradation Rates," Lewis Publishers, Inc.
- (2) ASTM, E-1739-95, Table X3.1

Table 2
CALCULATION OF DILUTION FACTOR (DF) USING DOMENICO'S EQUATION
(LHAAP-12, Longhorn Army Ammunition Plant, Texas)

(Vinyl Chloride)
VC Discharged to Central Creek
(Assumed VC half-life = 8.0 years [Howard et al., 1991]⁽¹⁾)

L	350 ft
alphaz1	1.75 ft
B	12.5 ft
Dv	12.4976 ft/year
I	0.042 ft/year
Aquifer thickness (H)	12.5 ft

Sw	150 ft	x	588.2 ft
effective n	0.25	alpha x	58.82 ft
lambda	0.087 1/yr	alpha y	19.61 ft
R	1.017272	alpha z	2.941 ft
I	0.016 ft/ft	Koc	2.54 cm ³ /g
K	781.1 ft/yr	foc	0.001
v	49.9904 ft/year	rho	1.7 g/cm ³

Calculations:

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft

Identify the following condition:

$$X_p = (H - S_d)^2 / \alpha_{phz} = 0.0000 \text{ ft}$$

Xp = 0.0 (i.e. Sd = H)

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft
DF DOMENICO	6.836

Parameters Definition, Assumptions and Sources

L	length of source parallel to groundwater flow in feet
alphaz1	vertical dispersivity in feet ($=L/200$) ⁽²⁾
B	thickness of shallow water bearing zone in feet
Dv	Darcy horizontal velocity in ft/yr ($=K \times i$)
I	infiltration rate in ft/yr
Sw	source width perpendicular to groundwater flow in feet
Sd	source thickness in feet (if $hadv+hdisp > B$, $Sd = B$ or else $Sd = hadv + hdisp$) (NOTE: The thickness of the impacted permeable zone shall be used if the thickness of the plume isn't known) $hadv = B[1 - \exp(-I \times L / (B \times Dv))]$ $hdisp = (2 \times \alpha_{phz1} \times L)^{1/2}$
effective n	effective porosity
lambda	first order degradation rate
R	retardation factor ($= 1 + (Kd \times \rho) / n$) where $Kd = Koc \times foc$ (Koc = soil sorption coefficient, assumed nitrate not adsorbed) (foc = fraction of organic carbon in soil = 0.1%, assumed for silty clay) ρ = bulk density = assumed 1.7 g/cm ³
I	hydraulic gradient
K	hydraulic conductivity in ft/yr
v	groundwater seepage velocity in ft/yr ($=K \times i / n$)
x	distance down gradient from source in feet
alpha x	longitudinal groundwater dispersivity in feet ($=0.1x$) ⁽²⁾
alpha y	transverse groundwater dispersivity in feet ($=\alpha_{phax} / 3$) ⁽²⁾
alpha z	vertical groundwater dispersivity in feet ($=\alpha_{phax} / 20$) ⁽²⁾

Reference:

- (1) Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M., Meylan, and E.M. Michalenko, 1991, "Environmental Degradation Rates," Lewis Publishers, Inc.
- (2) ASTM, E-1739-95, Table X3.1

Table 3
CALCULATION OF DILUTION FACTOR (DF) USING DOMENICO'S EQUATION
(LHAAP-12, Longhorn Army Ammunition Plant, Texas)

(Perchlorate)
Perchlorate Discharged into Central Creek

L	350 ft
alphaz1	1.75 ft
B	12.5 ft
Dv	12.4976 ft/year
I	0.042 ft/year
Aquifer thickness (H)	12.5 ft

Sw	150 ft	x	588.2 ft
effective n	0.25	alpha x	58.82 ft
lambda	0 1/yr	alpha y	19.61 ft
R	1	alpha z	2.941 ft
I	0.016 ft/ft	Kd	0 cm ³ /g
K	781.1 ft/yr	foc	
v	49.9904 ft/year	rho	1.7 g/cm ³

Calculations:

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft

Identify the following condition:

$$X_p = (H - S_d)^2 / \alpha_{paz} = 0.0000 \text{ ft}$$

Xp = 0.0 (i.e. Sd = H)

hadv	1.12 ft
hdisp	35 ft
Sd (Method 1)	12.50 ft
Sd (Method 2)	12.5 ft
DF DOMENICO	2.641

Parameters Definition, Assumptions and Sources

L	length of source parallel to groundwater flow in feet
alphaz1	vertical dispersivity in feet ($= L/200$) ⁽²⁾
B	thickness of shallow water bearing zone in feet
Dv	Darcy horizontal velocity in ft/yr ($= K \times i$)
I	infiltration rate in ft/yr
Sw	source width perpendicular to groundwater flow in feet
Sd	source thickness in feet (if $hadv + hdisp > B$, $Sd = B$ or else $Sd = hadv + hdisp$) (NOTE: The thickness of the impacted permeable zone shall be used if the thickness of the plume isn't known) $hadv = B[1 - \exp(-I \times L) / (B \times Dv)]$ $hdisp = (2 \times \alpha_{paz1} \times L)^{1/2}$
effective n	effective porosity
lambda	first order degradation rate
R	retardation factor ($= 1 + (Kd \times \rho) / n$) where $Kd = Koc \times foc$ (Koc = soil sorption coefficient, assumed nitrate not adsorbed) (foc = fraction of organic carbon in soil = 0.1%, assumed for silty clay) ρ = bulk density = assumed 1.7 g/cm ³
I	hydraulic gradient
K	hydraulic conductivity in ft/yr
v	groundwater seepage velocity in ft/yr ($= K \times i / n$)
x	distance down gradient from source in feet
alpha x	longitudinal groundwater dispersivity in feet ($= 0.1x$) ⁽¹⁾
alpha y	transverse groundwater dispersivity in feet ($= \alpha_{paz} / 3$) ⁽¹⁾
alpha z	vertical groundwater dispersivity in feet ($= \alpha_{paz} / 20$) ⁽¹⁾

Reference:

(1) ASTM, E-1739-95, Table X3.1

Table 4
Calculation of Flow Discharge in Central Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (ft ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.09341	1.11074	0.11183	1.29100	6.10	6.31	0.6822	8.1462	4.4142
	10 - 16	0.07876	1.48660	0.14567	0.25542	4.40	7.30	0.6409	1.8646	1.253
	17 - 23	0.03000	1.46344	0.11000	0.73705	2.00	7.25	0.2200	5.3436	2.782
	24 - 30	0.03000	1.32520	0.11000	0.23729	2.00	7.00	0.2200	1.6610	0.941
Jan-00	1 - 7	0.03000	1.06090	0.11000	0.29642	3.90	11.90	0.4290	3.5274	1.978
	8 - 14	0.07554	1.62076	0.13253	0.19877	2.50	10.80	0.3313	2.1467	1.239
	15 - 21	0.03000	1.48365	0.07000	0.15027	2.50	7.20	0.1750	1.0819	0.628
	22 - 28	0.04400	1.36087	0.08400	3.31644	8.50	11.00	0.7140	36.4808	18.597
Feb-00	1 - 7	0.05970	1.63820	0.05752	0.54047	2.00	6.12	0.1150	3.3077	1.711
	8 - 14	0.03500	1.51571	0.03000	0.25153	4.20	11.70	0.1260	2.9429	1.534
	15 - 21	0.03500	1.44892	0.03000	1.64454	2.00	7.26	0.0600	11.9394	6.000
	22 - 28	0.04400	1.55024	0.08400	0.25240	2.80	7.15	0.2352	1.8047	1.020
Mar-00	1 - 7	0.06586	2.07625	0.05766	3.62250	4.10	17.90	0.2364	64.8428	32.540
	8 - 14	0.19663	2.40898	0.28986	2.59353	12.00	25.30	3.4783	65.6163	34.547

Notes:

Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

ft² square feet

cfs cubic feet per second

Table 5
Summary of Derivation of Dilution Factors and Medium Specific Concentrations (MSCs)

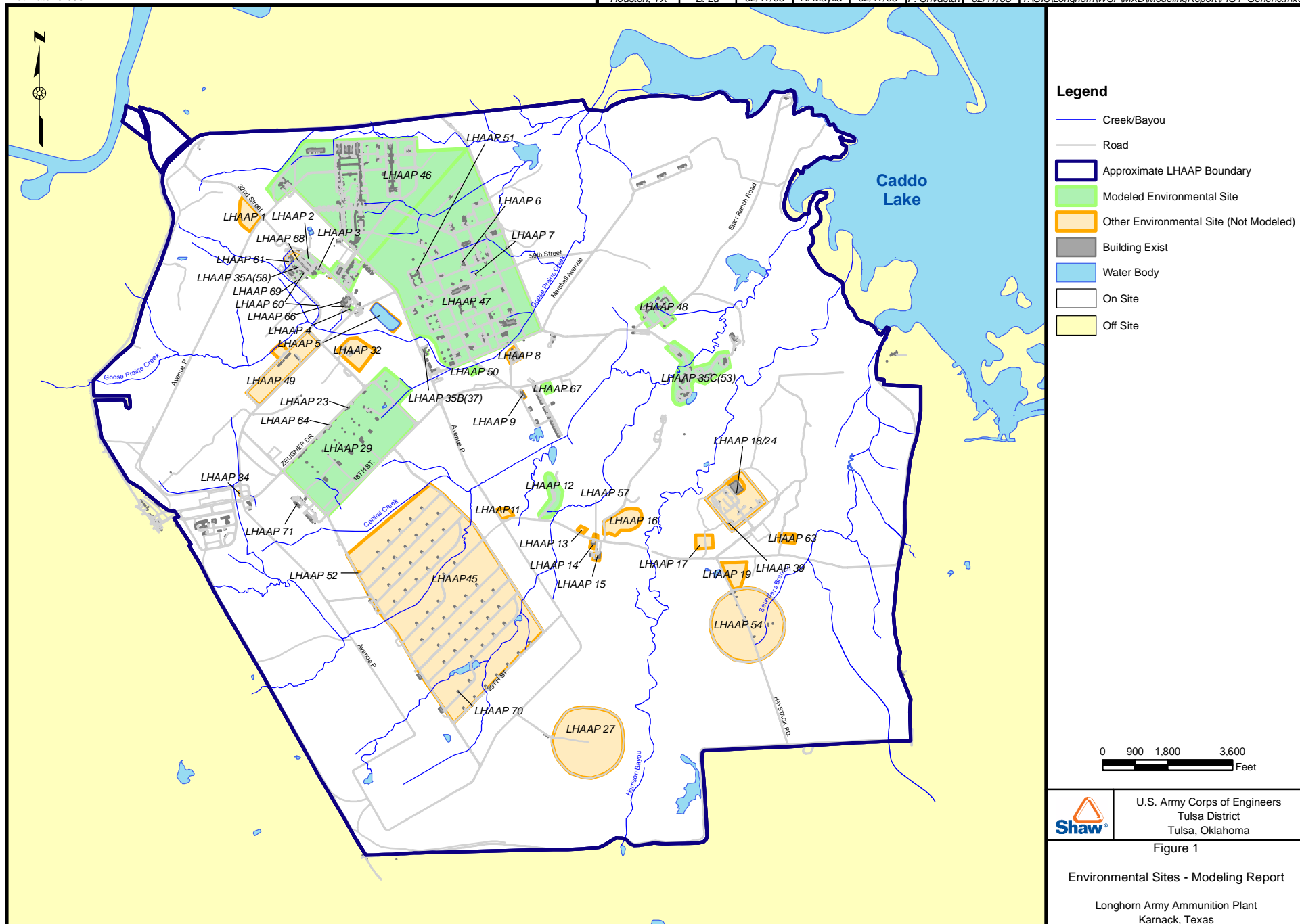
Chemical of Concern	Maximum Concentration at Source (µg/L)	Dilution Factor (DF) at the POE into Central Creek	Concentration at the POE into Central Creek (µg/L)	MSC Based on DF at the POE into Central Creek (µg/L)	Dilution Factor (DF) at POE into Central Creek	Mixing Concentration after Discharge into Central Creek (µg/L)	MSC Based on DF after Discharge into Central Creek (µg/L)
Perchlorate	56.0	2.641	21.2	10.56	1,474	0.038	5,895
TCE	495.0	30.485	16.23	152.45	16,500	0.03	82,500
VC	2.1	6.836	0.307	13.67	---	---	---

Abbreviations:

POE point of entry
TCE trichloroethene
VC vinyl chloride
µg/L micrograms per Liter

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd



Plot Date: 01/31/05
Revision Format: 10/08/04

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	S. Brown	A. Mayila	P. Srivastav	X:\Longhorn\GIS\workspace\MXD\Fig11-2.mxd

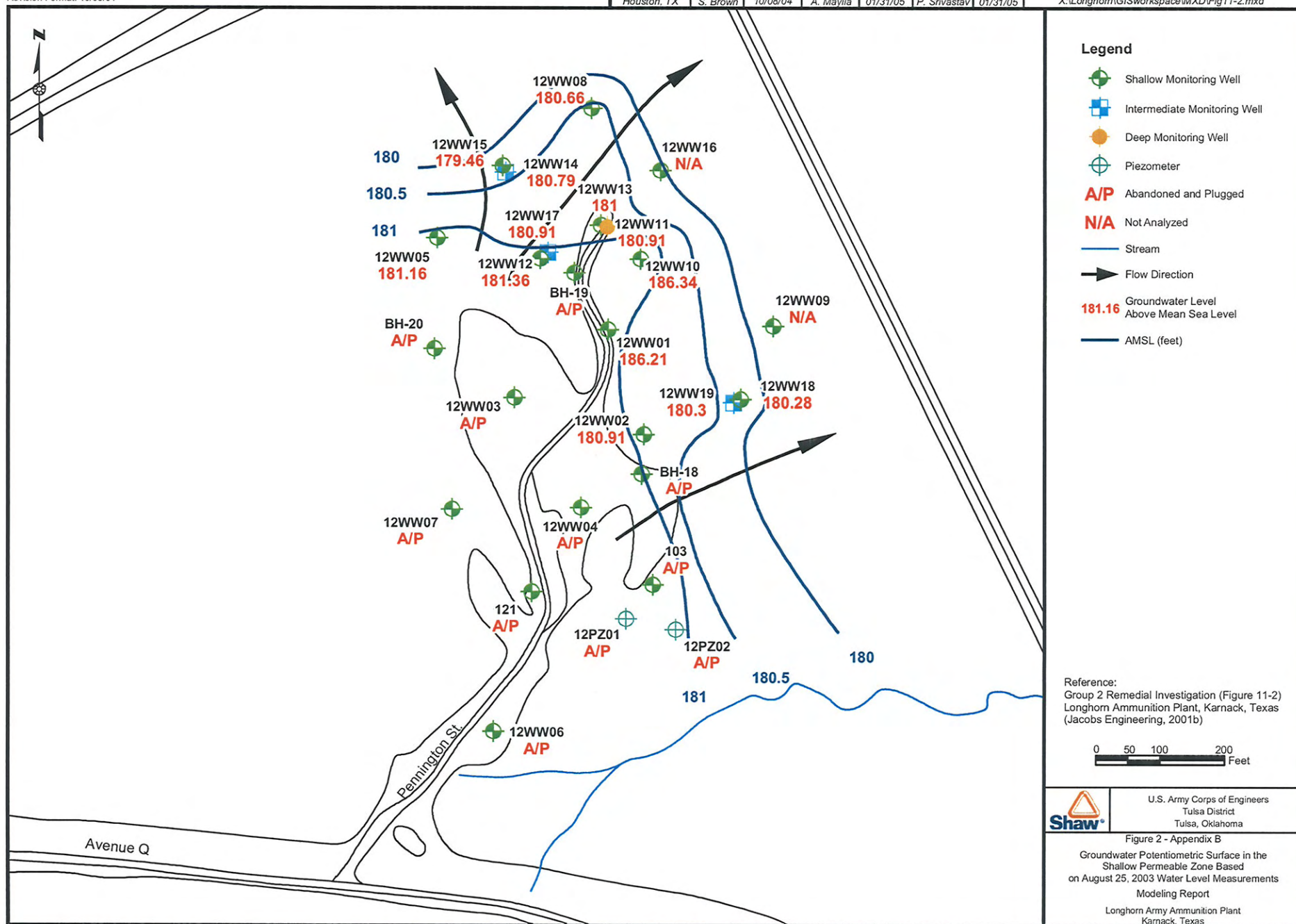
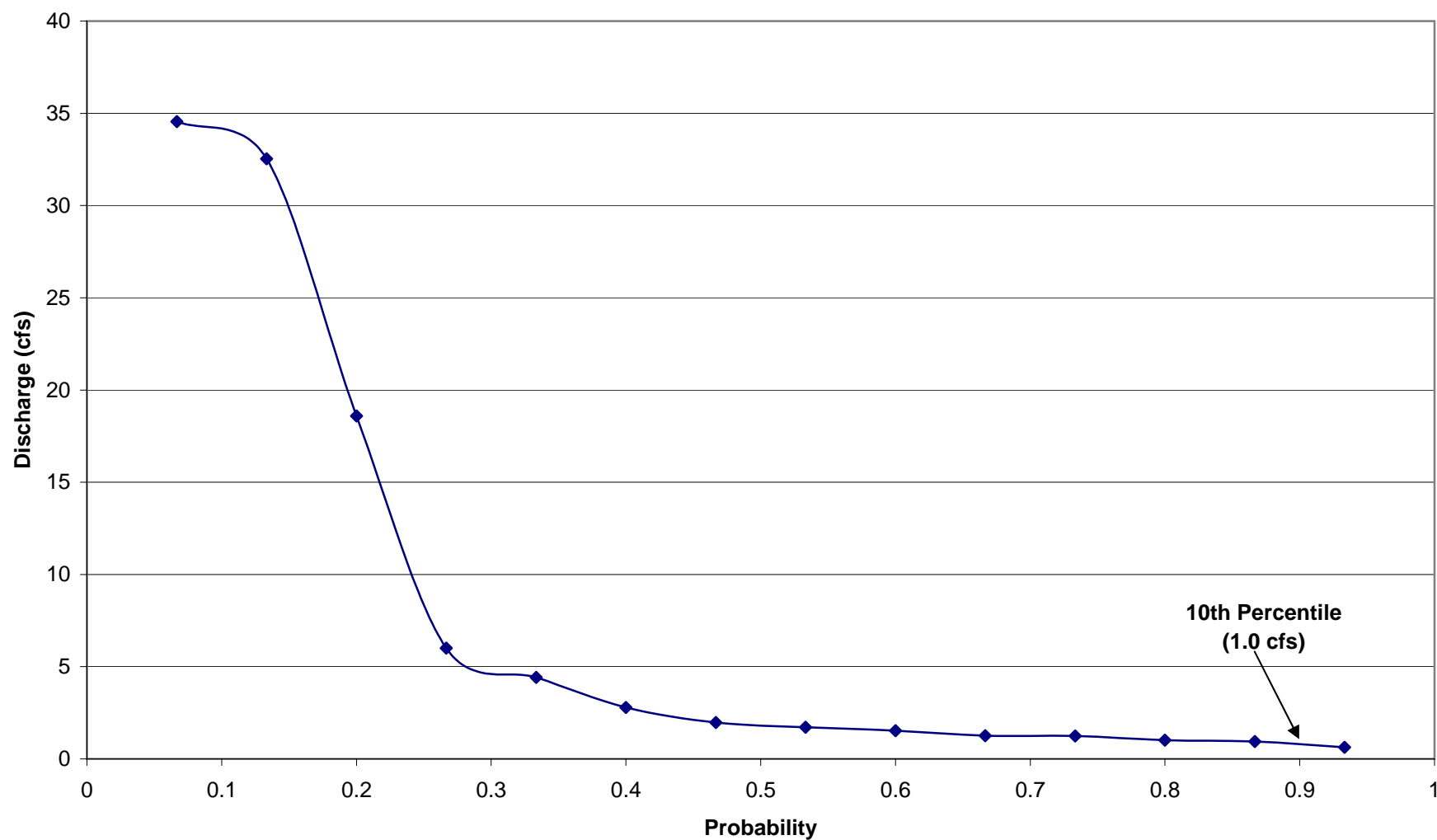


Figure 3 - Appendix B
7Q2 Low Flow Analysis
Probability vs Flow Discharge for Central Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix C

LHAAP-29, Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Simulation and Results	3-1
3.1	Dilution in Central Creek.....	3-1
4.0	Summary and Conclusions	4-1
5.0	References	5-1

List of Tables

Table 1	Chemical Properties for LHAAP-29 Groundwater Fate and Transport Modeling
Table 2	Summary of 1,2-DCA, TCE, Methylene Chloride and Perchlorate Concentrations at Central Creek
Table 3	Calculation of Flow Discharge in Central Creek

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	LHAAP-29 Shallow Potentiometric Surface Map (August 1998)
Figure 3	Simulated Perchlorate Concentrations in Groundwater at Central Creek
Figure 4	7Q10 Low Flow Analysis, Probability vs Flow Discharge for Central Creek, Based on December 1999 to March 2000 Flow Derivation

1.0 Introduction

LHAAP-29 is located on the western central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-29 was a trinitrotoluene (TNT) production area. The chemicals of concern (COC) in groundwater are methylene chloride, 1,2-dichloroethane, trichloroethene (TCE), and perchlorate at maximum concentrations of 6,600,000, 14,000, 1,200, and 61,400 µg/L, respectively (Jacobs, 2001b; Jacobs, 2001c; Solutions to Environmental Problems, Inc., 2003). The COC concentrations are higher than the maximum contaminant levels (MCLs) and interim action level (IAL) for perchlorate.

The purpose of the modeling was to calculate the maximum concentrations and dilution factors for each COC at the point of entry (POE) of the groundwater into the surface water. The purpose was also to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the MCLs or IAL for perchlorate. The closest surface water body downgradient from the detected maximum contamination (29WW15 and 29WW16) at the site is Central Creek at a distance of approximately 6,125 feet (**Figure 1**). Groundwater flows to the southeast from this location, then northeast based on August 1998 water level measurements (**Figure 2**).

In order to calculate the maximum concentrations of the COCs and the time of travel to the POE at Central Creek, the computer program AT123D was used.

2.0 *Input Parameters and Assumptions*

Groundwater modeling at LHAAP-29 was based on the following assumptions and considerations:

- Contaminant source: Instantaneous source extending across the entire aquifer thickness of 10 feet was assumed. The only source is the plume itself.
- The source area was assumed to be the plume area. The dimensions of the plume were assumed to be 1,250 feet (east-west) by 375 feet (north-south) by 10 feet (depth) for all the contaminants.
- Based on the geologic cross-sections at LHAAP-29 (Jacobs, 2001b), the thickness of the shallow water-bearing zone consisting of sand is in the range of 5 to 15 feet. Therefore, an average depth of 10 feet was used. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 10 feet.
- The properties of the shallow water bearing zone used in the model were as follows:
 - Average hydraulic conductivity (K) based on the slug tests at LHAAP-29 was estimated to be 6.79×10^{-4} cm/sec (Jacobs, 2001b)
 - Hydraulic gradient: 0.01feet/feet (based on the potentiometric surface map for water level measurements from August 1998 (Jacobs, 2001b). The potentiometric surface map constructed based on 2005 groundwater level measurements shows little difference from that of August 1998.
 - Effective porosity assumed at 0.25
 - Longitudinal groundwater dispersivity: $= x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) where x is the travel distance of contaminants, assumed to be the distance from the source to the Central Creek = 612 feet.
 - Transverse groundwater dispersivity: $= \alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995) = 62.2 feet
 - Vertical groundwater dispersivity: $= \alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995) = 9.34 feet

Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 1**.

3.0 Simulation and Results

Computer simulation results were evaluated at the POE as shown in **Table 2**. The results include the time when COCs reach the POE, the time they reach their peaks, the maximum concentrations at this location, the dilution factors, and the MSC based on DF and the action level.

Simulation shows that except for perchlorate, no other COC will reach Central Creek. Perchlorate will take 176 years to reach Central Creek at a concentration of 1,634 µg/L (**Table 2** and **Figure 3**). The maximum concentration of perchlorate exceeds the IAL of 4 µg/L. The dilution factor calculated for perchlorate is 37.6 at the POE (**Table 2**).

3.1 Dilution in Central Creek

Because perchlorate exceeds the IAL in groundwater at the POE, further evaluation of its mixing and dilution in the Central Creek was performed.

The DF of perchlorate after mixing with surface water in the Central Creek is calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW} + Q_{CC}}{Q_{GW}} \quad \text{Equation C1}$$

Where:

Q_{CC} and Q_{GW} are the flow rates in the Central Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} \times \delta_p \times L_m \quad \text{Equation C2}$$

Where:

U_{gw} , δ_p , and L_m are the approaching groundwater seepage velocity, the thickness, and width of the plume approaching surface water, respectively.

U_{gw} is calculated based on the hydraulic conductivity of 6.79×10^{-4} cm/sec, hydraulic gradient of 0.01 and the effective porosity of 0.25. Therefore groundwater seepage velocity is 0.077 ft/day.

δ_p is 10 feet and L_m is unknown at the intersection but can be conservatively assumed as one-half the width of the source, which is 188 feet since the source is 6125 feet away. Then:

$$DF = (1.68 \times 10^{-3} + 1.0) / (1.68 \times 10^{-3}) = 596.2$$

Calculation of Q_{CC} has to be based on the 7Q2 stream flow analysis. 7Q2 is the low flow at the point of interest, defined as the flow discharge in seven consecutive days that occurs once every ten years statistically. At Central Creek, only two sets of stream data at the upstream and downstream cross sections are available from the U.S. Army Corps of Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained during the period of December 1999 to March 2000, a total of only four months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period are calculated and presented in **Table 3**. Note that there is no observation at the point where contaminated groundwater flow discharges into Central Creek, average values between upstream and downstream flow are used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 1.0 cubic feet per second (cfs) is derived (**Figure 4**).

The mixing concentration for perchlorate in Central Creek is 2.74 µg/L.

This concentration is below perchlorate IAL of 4 µg/L.

The mixing concentrations and the overall MSC for perchlorate are presented in **Table 2**.

4.0 *Summary and Conclusions*

Results of the modeling indicate that the three COCs; TCE, methylene chloride, and 1,2-DCA will not reach Central Creek. The COC perchlorate reaches the creek at 1,634 $\mu\text{g/L}$ in groundwater; however, perchlorate is mixed and diluted in surface water to a concentration of 2.74 $\mu\text{g/L}$, a level below the action level of 4 $\mu\text{g/L}$. The current maximum perchlorate concentration at the source, 61,400 $\mu\text{g/L}$, is lower than the MSC value protective of surface water 89,635 $\mu\text{g/L}$.

Field Confirmation

Additional calculations were conducted to simulate perchlorate concentrations at a well located in a transverse direction from the centerline of the flow. These calculations were conducted to compare the model results with actual field observations.

The computer modeling provides a maximum simulated concentration of 154 $\mu\text{g/L}$ of perchlorate after 91 years at monitoring well 117. Monitoring well 117 is situated at a lateral distance of 691 feet away from the center line of flow path, 380 feet downgradient from the source location (29WW15 and 29WW16). Recent observation of perchlorate shows non-detect at well 117 (Solutions to Environmental Problems, Inc., 2003).

5.0 *References*

References are provided in the main document, Section 8.0.

Table 1
Chemical Properties for LHAAP-29 Groundwater Fate and Transport Modeling

Chemical	Koc ⁽¹⁾ (cm ³ /g)	foc (percent)	Kd (cm ³ /g)	Kd (m ³ /kg)	Half-life (years) ⁽²⁾	Degradation Rate (1/year)
Methylene Chloride	27.5	0.1	0.0275	2.75E-05	1 ⁽³⁾	0.694
1,2-Dichloroethane	31.6	0.1	0.0316	3.16E-05	1	0.694
Trichloroethene	100	0.1	0.1	1.00E-04	4.5	0.154
Perchlorate	---	---	0	0.00E+00	---	0

Notes:

Sources: (1) Montgomery, 2000, *Groundwater Chemicals - Desk Reference (Third Edition)*

(2) Howard et al., 1991, *Environmental Degradation Rates*

(3) Use dichloromethane (synonym of methylene chloride) value in (2), i.e., 8 weeks. Conservatively 1 year was used.

Koc carbon-water sorption coefficient

cm³/g cubic centimeters per gram

m³/kg cubic meters per kilogram

kd distribution coefficient

foc fraction organic carbon

Table 2
Summary of 1,2-DCA, TCE, Methylene Chloride and Perchlorate Concentrations
at Central Creek (6125 feet Downgradient from Source)
LHAAP-29, Longhorn Army Ammunition Plant

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Central Creek (feet)	Source Release Rate* (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration at POE into Central Creek (µg/L) (DF)	MSC Based on DF at POE into Central Creek (µg/L)	Mixing Concentration after Discharge in Central Creek (µg/L)	Overall MSC after Discharge into Central Creek (µg/L)
1,2-Dichloroethane	5.0	375 x 1250	14,000	6,125	649.300	Infinity	0 (Infinity)	Infinity	NA	NA
Trichloroethene	5.0	375 x 1250	1,200.0	6,125	55.700	Infinity	0 (Infinity)	Infinity	NA	NA
Methylene Chloride	5.0	375 x 1250	6,600,000	6,125	306,095.0	Infinity	0 (Infinity)	Infinity	NA	NA
Perchlorate	4 ⁽¹⁾	375 x 1250	61,400.0	6,125	2,848.0	20.0	1,634 (176 Years) (37.6)	150.4	2.74	89,635

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 10 feet.

* Instantaneous source release in kg = maximum source concentration x plume pore volume

⁽¹⁾ Texas interim action level

DF dilution/attenuation factor

MSC medium specific concentration

Table 3
Calculation of Flow Discharge in Central Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (ft)		Measured Velocity (ft/s)		Cross Sectional Area (ft ²)		Calculated Discharge (cfs)		Average Discharge
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	(cfs)
Dec-99	3 - 9	0.09341	1.11074	0.11183	1.29100	6.10	6.31	0.6822	8.1462	4.4142
	10 - 16	0.07876	1.48660	0.14567	0.25542	4.40	7.30	0.6409	1.8646	1.253
	17 - 23	0.03000	1.46344	0.11000	0.73705	2.00	7.25	0.2200	5.3436	2.782
	24 - 30	0.03000	1.32520	0.11000	0.23729	2.00	7.00	0.2200	1.6610	0.941
Jan-00	1 - 7	0.03000	1.06090	0.11000	0.29642	3.90	11.90	0.4290	3.5274	1.978
	8 - 14	0.07554	1.62076	0.13253	0.19877	2.50	10.80	0.3313	2.1467	1.239
	15 - 21	0.03000	1.48365	0.07000	0.15027	2.50	7.20	0.1750	1.0819	0.628
	22 - 28	0.04400	1.36087	0.08400	3.31644	8.50	11.00	0.7140	36.4808	18.597
Feb-00	1 - 7	0.05970	1.63820	0.05752	0.54047	2.00	6.12	0.1150	3.3077	1.711
	8 - 14	0.03500	1.51571	0.03000	0.25153	4.20	11.70	0.1260	2.9429	1.534
	15 - 21	0.03500	1.44892	0.03000	1.64454	2.00	7.26	0.0600	11.9394	6.000
	22 - 28	0.04400	1.55024	0.08400	0.25240	2.80	7.15	0.2352	1.8047	1.020
Mar-00	1 - 7	0.06586	2.07625	0.05766	3.62250	4.10	17.90	0.2364	64.8428	32.540
	8 - 14	0.19663	2.40898	0.28986	2.59353	12.00	25.30	3.4783	65.6163	34.547

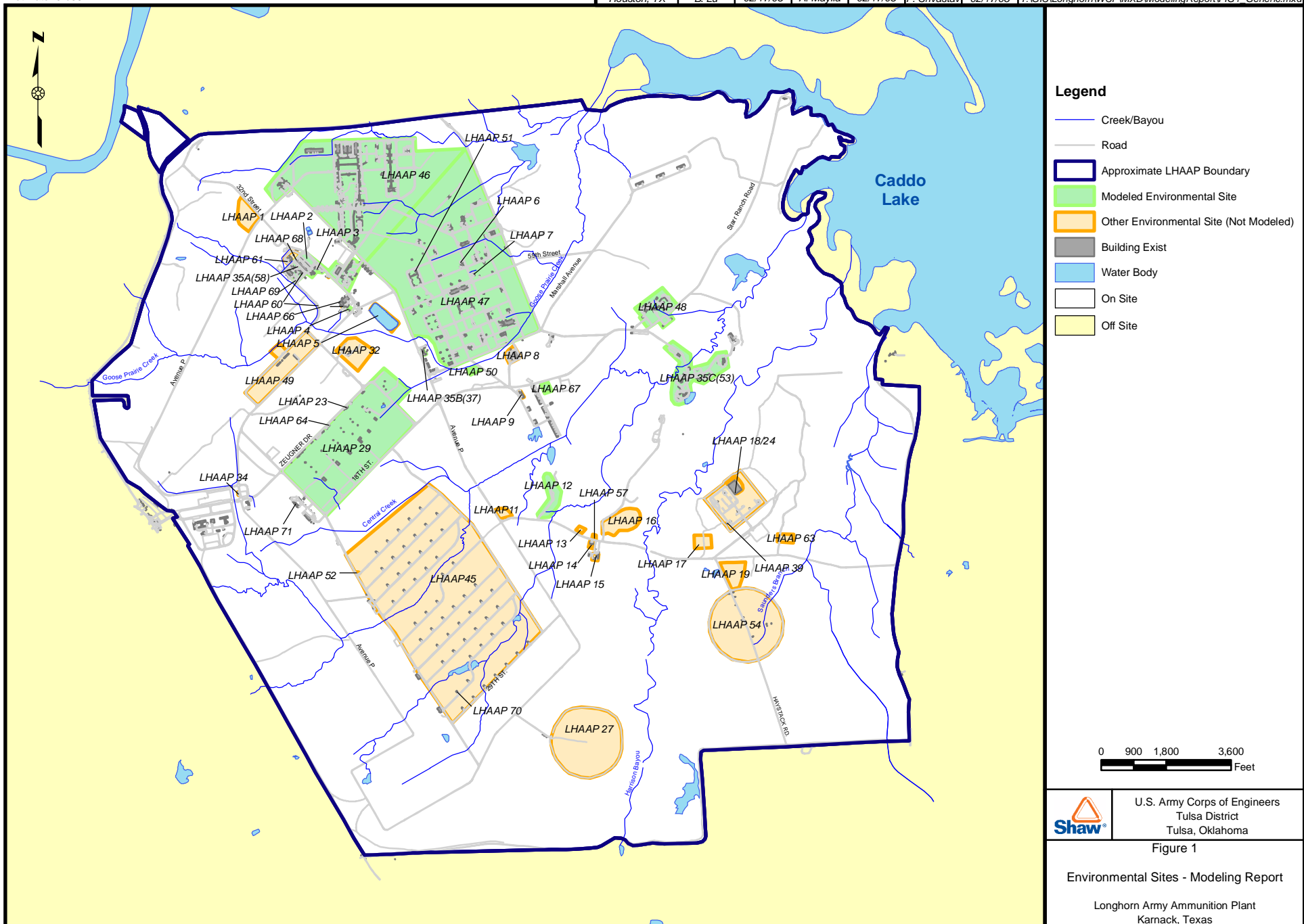
Notes:

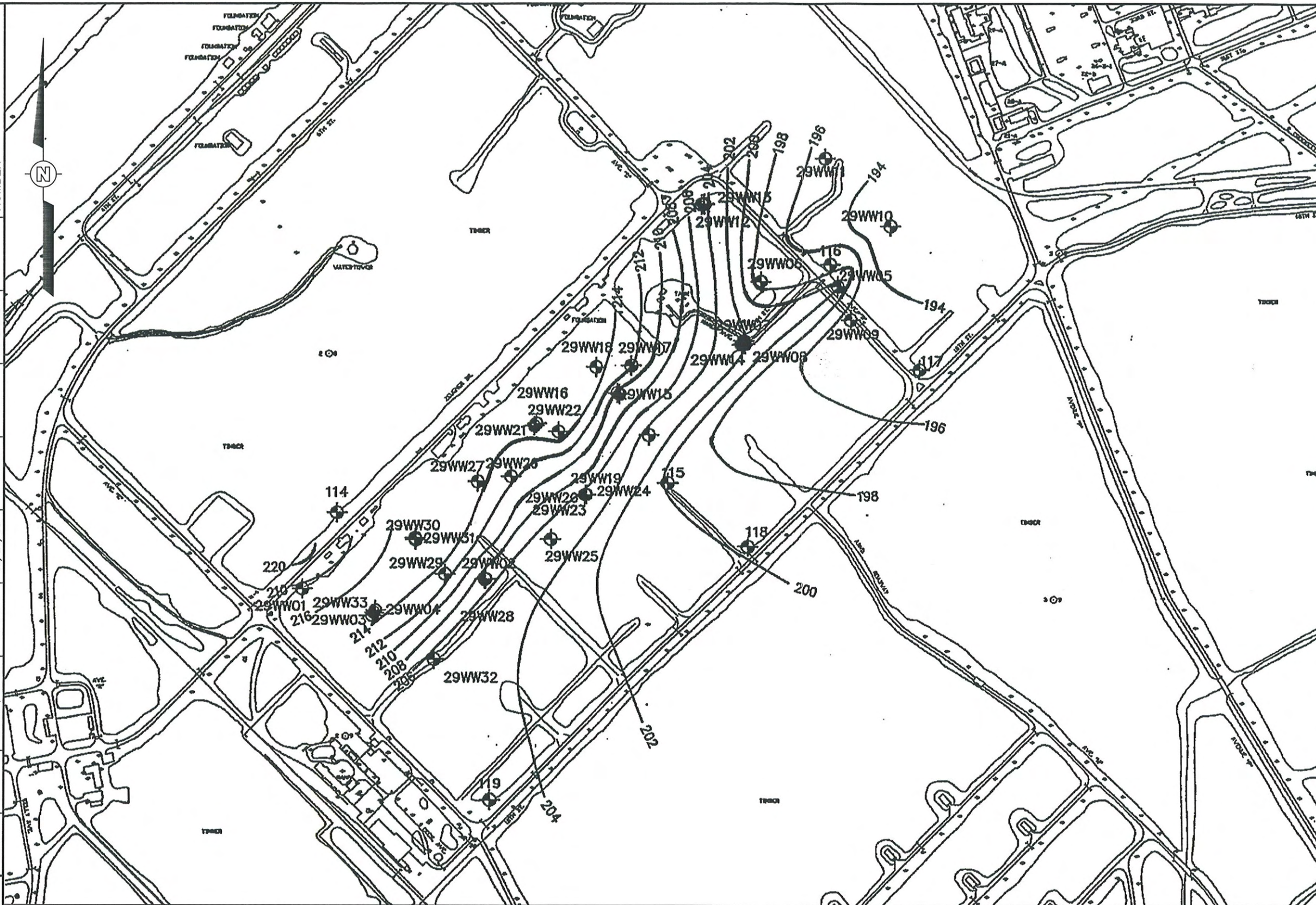
Measured depths and measured velocities are averaged values over every seven days.

Cross sectional areas are based on the measured depths and cross sections in Attachment D.

Average flow discharges are the average values of upstream and downstream discharges.

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\Modeling\Report\FIG1 Generic.mxd





LEGEND			
	SURFACE WATER SAMPLE POINT		PIEZOMETER
	SEDIMENT SAMPLE POINT		DEEP MONITORING WELL
	SHALLOW MONITORING WELL		ABANDONED AND PLUGGED
	INTERMEDIATE MONITORING WELL		
	POTENTIOMETRIC SURFACE CONTOUR		

Well ID	Elevation (ft)
114	220.73
115	198.85
116	197.15
117	194.6
118	199.99
119	204.41
29WW01	217.25
29WW02	206.49
29WW03	214.41
29WW05	200.23
29WW06	196.61
29WW07	202.07
29WW09	194.91
29WW10	192.84
29WW11	195.34
29WW12	204.12
29WW15	209.31
29WW17	212.06
29WW18	214.96
29WW19	203.57
29WW20	214.23
29WW22	214.02
29WW23	205.9
29WW25	204.09
29WW26	212.09
29WW27	214.14
29WW29	213.74
29WW30	215.09
29WW32	204.92

Figure 3 - Appendix C
Simulated Perchlorate Concentrations in Groundwater
at Central Creek
LHAAP-29, Longhorn Army Ammunition Plant, Texas

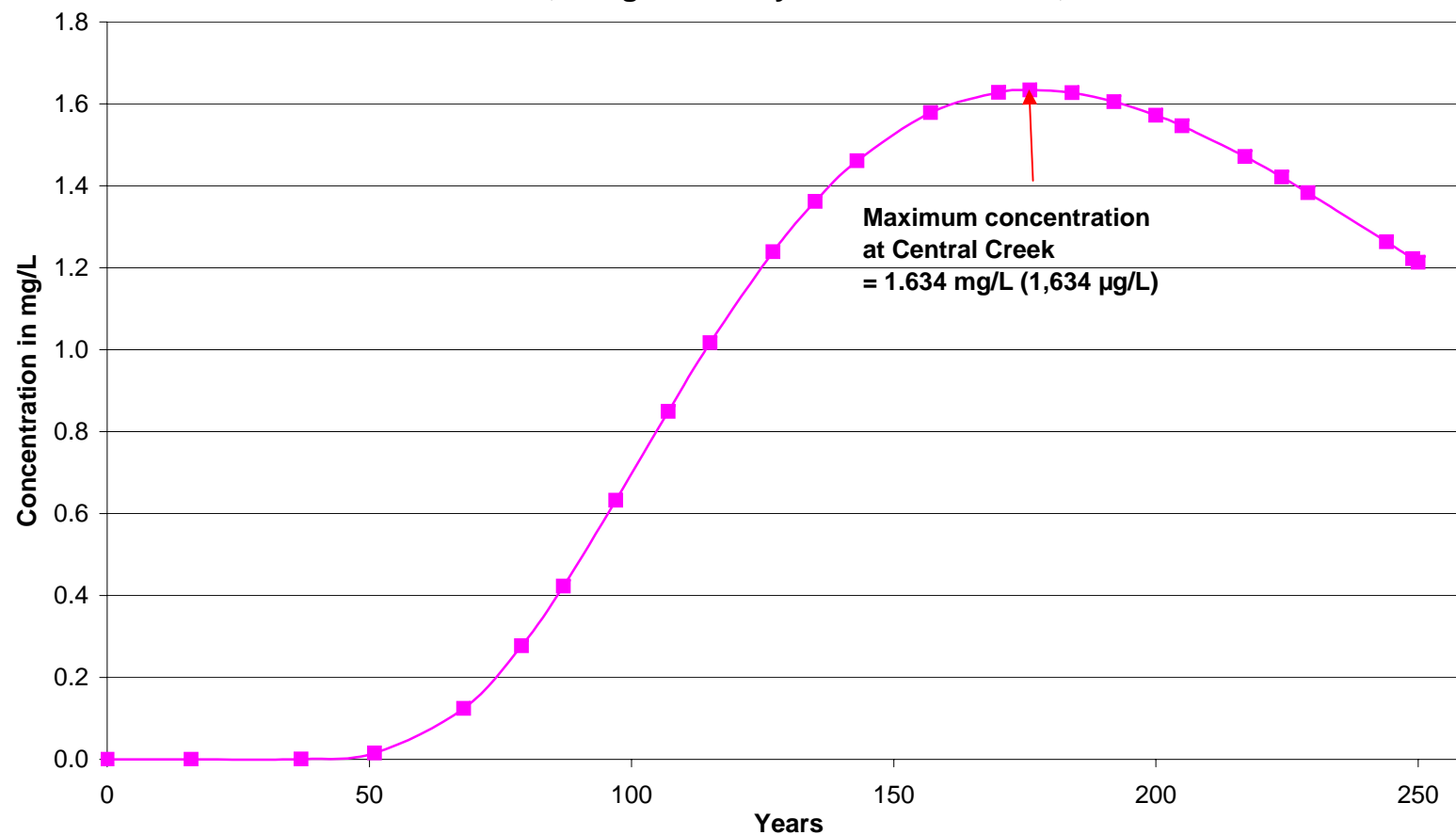
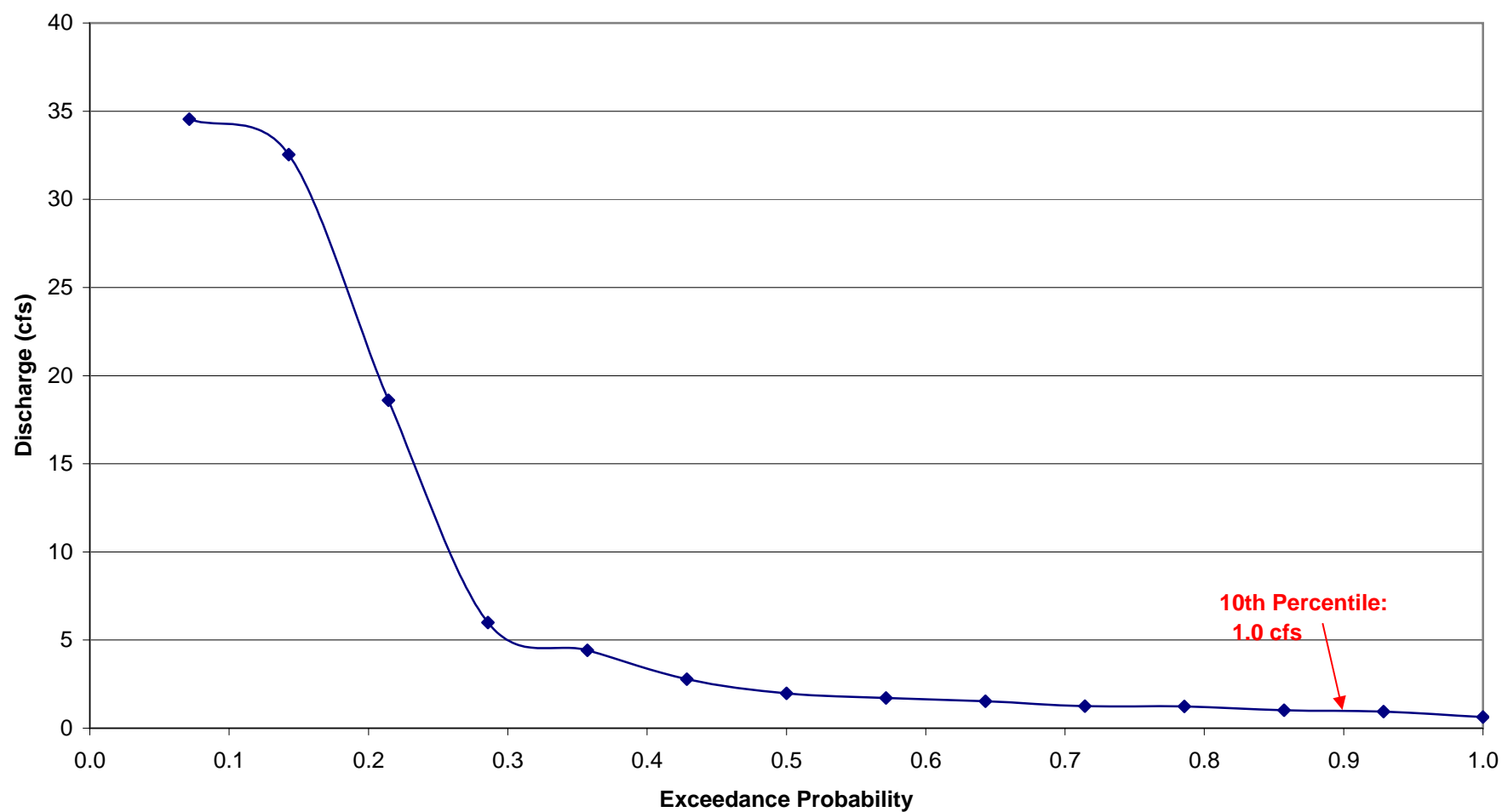


Figure 4 - Appendix C
7Q2 Low Flow Analysis
Probability vs Flow Discharge for Central Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix D

*LHAAP-35A(58) Calculation of Maximum Concentrations
and Dilution Factors of Contaminants Discharged to Goose
Prairie Creek from Groundwater*

Table of Contents

1.0	Introduction	1-1
2.0	Computer Code and Methodology	2-1
2.1	Groundwater Modeling	2-1
2.1.1	Input Parameters	2-1
2.1.2	Modeling Results and Dilution Factors	2-2
2.1.3	Dilution in Goose Prairie Creek	2-2
3.0	Summary and Conclusions	3-1
4.0	References	4-1

List of Tables

Table 1	Maximum Concentrations and Chemical Properties for COCs at LHAAP-35A(58)
Table 2	Summary of 1,1-DCE, TCE, PCE, RDX and Perchlorate Concentrations at Goose Prairie Creek
Table 3	Calculation of Flow Discharge in Goose Prairie Creek

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	LHAAP-04 and LHAAP-35A(58) Site Map
Figure 3A	Shallow Groundwater Elevation Contour Map (December 1998 Data)
Figure 3B	Shallow Groundwater Elevation Contour Map (September 2000 Data)
Figure 4	RDX Concentrations in Groundwater at Goose Prairie Creek
Figure 5	Perchlorate Concentrations in Groundwater at Goose Prairie Creek
Figure 6	Low Flow Analysis, Probability vs Flow Discharge for Goose Prairie Creek, based on December 1999 to March 2000 Flow Derivation

1.0 Introduction

LHAAP-35A(58) is located in the northwestern portion of Longhorn Army Ammunition Plant with LHAAP-61 to the north, LHAAP-4 to the southeast, LHAAP-49 to the southwest, and LHAAP-51 to east (**Figure 1**). This site is referred to as the Maintenance Complex.

The chemicals of concern (COC) in the groundwater at LHAAP-35A(58) are 1,1-dichloroethene (1,1-DCE), 1,1,2-trichloroethane (1,1,2-TCA), trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride (VC), bis(2-ethylhexyl)phthalate, RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), and perchlorate which were detected at elevated concentrations above their respective MCLs, medium-specific concentration (MSC) or interim action level (IAL) for perchlorate, as listed in **Table 1**. This is based on data presented in the remedial investigation reports (Jacobs, 2002a and 2001b).

The purpose of the following modeling was to calculate the maximum concentrations and the dilution factors of these COCs in the groundwater at the point of entry (POE) into the nearest surface water body, Goose Prairie Creek, and thereby derive the concentrations protective of surface water. Among these COCs, 1,1,2-TCA, VC, and bis(2-ethylhexyl)phthalate were not modeled for their transport in groundwater because of either their low concentrations (8 µg/L, 10 µg/L, and 88.3 µg/L), high adsorption (70.8 cm³/g, 11.0 cm³/g, and 87,016 cm³/g), or short half-life (2 years, 2 to 8 years, and 1.1 year). These COCs are not expected to reach Goose Prairie Creek which is 6,000 to 8,000 feet away).

Goose Prairie Creek is located approximately 120 feet to the west of LHAAP-35A(58) (**Figure 2**). Goose Prairie Creek flows from west to east, southeast and northeast to Caddo Lake. Because groundwater flows in the same direction as surface water in general (**Figures 3A** and **3B**), contaminant particles in the groundwater at LHAAP-35A(58) will not travel to the southwest or west but to the east until they reach Goose Prairie Creek approximately 6,319 feet (straight line) to 8,000 feet downgradient of the site.

The purpose of this calculation was to estimate COCs transport from groundwater to surface water (Goose Prairie Creek). The maximum concentrations in surface water as well as the dilution factors (DFs) of COCs at the POE and after discharge into the surface water were calculated and then the Medium Specific Concentrations (MSCs) were developed.

2.0 Computer Code and Methodology

The objectives of this modeling effort were achieved by applying the computer code AT123D.

2.1 Groundwater Modeling

As mentioned previously, the transport of 1,1-DCE, TCE, PCE, RDX and perchlorate in groundwater was modeled for LHAAP-35A(58).

2.1.1 Input Parameters

The input data for the groundwater model are described as follows:

- **Contaminant source.** Conservatively, the maximum concentrations of COCs to be modeled were assumed to cover the entire plume area of 600 feet (east-west) by 500 feet (north-south) (**Table 2**). The maximum concentration of PCE was detected in monitoring well LHS-MW-05 at a concentration of 5,400 µg/L on 5/13/1998 (Jacobs, 2002a). However, the diluted field duplicate was analyzed at 49,010 µg/L (Table 5-7 in Jacobs 2002a and Appendix C in Jacobs 2002b). It was not certain how this high value was derived. In the current modeling, this high value was used as a very conservative approach. Based on the geologic cross sections at LHAAP-35A(58) (Jacobs, 2002a), the thickness of the shallow water bearing zone is 2 to 5 feet. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 5 feet.
 - **Distance to Goose Prairie Creek.** The shortest distance from LHAAP-35A(58) to Goose Prairie Creek is only 120 feet to the west and southwest. However, groundwater flows to the southeast and east (**Figures 3A and 3B**) and the distance to Goose Prairie Creek was conservatively considered as the straight line distance of approximately 6319 feet (**Figure 3A**).
 - **Aquifer and Chemical Properties.** The following properties and parameters were the inputs to AT123D model:
 - **Hydraulic conductivity (K).** The average hydraulic conductivity, based on the slug tests at LHAAP-35A(58) (Table 5-1, Jacobs, 2002a) was estimated to be 6.36×10^{-4} cm/sec.
 - **Hydraulic gradient.** 0.0072 feet/foot (based on potentiometric surface map in Figure 2-1, Jacobs, 2002a);
 - Effective porosity: assumed 0.25
- α_x = longitudinal groundwater dispersivity (feet) = $x \cdot 0.1$
(ASTM, 1995, Table x3.1) where x is the travel distance of contaminants, i.e., 6,319 feet from the source to Goose Prairie Creek.

Therefore $\alpha_x = 631.9$ feet.

α_y = transverse groundwater dispersivity (feet) = $\alpha_x / 3$ (ASTM, 1995, Table x3.1),
i.e., 210.6 feet.

α_z = vertical groundwater dispersivity (feet) = $\alpha_x / 20$ (ASTM, 1995, Table x3.1),
i.e., 31.6 feet.

Chemical properties for each COC including the organic carbon partition coefficient (K_{oc}), water-soil distribution coefficient and half-life are listed in **Table 1**.

2.1.2 Modeling Results and Dilution Factors

The simulation time step was one year with a total simulation period of 100 to 700 years, long enough to capture the maximum concentrations of each contaminant occurring at the POE, where groundwater discharges into Goose Prairie Creek. Computer simulation results were evaluated at the POE as shown in **Table 2**. These results include the time when COCs reach the POE, the time they reach their peaks, the maximum concentrations at this location, the DFs and the MSC based on DF and the action level. As shown on **Table 2**, 1,1-DCE, TCE and PCE do not reach the POE, whereas RDX and perchlorate take 134 years and 58 years, respectively, to reach the POE at very low levels. RDX and perchlorate reach their peaks after 655 years and 284 years at concentrations of 12.75 $\mu\text{g/L}$ and 12.43 $\mu\text{g/L}$, respectively (**Table 2** and **Figures 4** and **5**).

While the maximum concentration of RDX at the POE (12.75 $\mu\text{g/L}$) is lower than its MSC of 26 $\mu\text{g/L}$, the maximum concentration of perchlorate at 12.43 $\mu\text{g/L}$ exceeds its IAL of 4 $\mu\text{g/L}$ by 3 times. The DFs calculated for RDX and perchlorate are 6.9 and 2.97, respectively, evaluated in the groundwater at the POE (**Table 2**).

2.1.3 Dilution in Goose Prairie Creek

Because perchlorate exceeds the IAL at the POE in groundwater, further evaluation of its mixing and dilution in the Goose Prairie Creek was performed.

The DF of perchlorate after mixing with surface water in Goose Prairie Creek is calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW} + Q_{CC}}{Q_{GW}} \quad \text{Equation D1}$$

Where:

Q_{CC} and Q_{GW} are the flow rates in Goose Prairie Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} * \delta_p * L_m \quad \text{Equation D2}$$

Where:

U_{gw} , δ_p and L_m are the approaching groundwater seepage velocity, the thickness and width of the plume approaching surface water.

U_{gw} ($= Ki/n$) is 18.95 feet/year, calculated based on the hydraulic conductivity of 6.36×10^{-4} cm/sec, hydraulic gradient of 0.0072 and the effective porosity of 0.25.

δ_p is 5 feet and L_m is unknown at the intersection but can be conservatively assumed as the width of the source, which is 500 feet.

Then:

$$Q_{GW} = 18.95 / (365 \times 86400) \times 5 \times 500 = 1.5 \times 10^{-3} \text{ feet}^3/\text{s}.$$

Calculation of Q_{CC} has to be based on the 7Q2 stream flow analysis. 7Q2 is the low flow at the point of interest, defined as the flow discharge in seven consecutive days that occurs once every two years statistically. At Goose Prairie Creek, only two sets of stream data at the upstream and downstream cross-sections are available, from the U.S. Army Corps of Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained during the period of December 1999 to March 2000, a total of only four months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period are calculated and presented in **Table 3**. Note that there is no observation at the point where contaminated groundwater flow discharges into Goose Prairie Creek, average values between upstream and downstream flow are used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 2.5 cubic feet per second (cfs) is derived (**Figure 6**).

Then:

$$DF = (1.5 \times 10^{-3} + 2.5) / (1.5 \times 10^{-3}) = 1667.7$$

The mixing concentration for perchlorate in Goose Prairie Creek contributed by LHAAP-35A(58) is:

$$12.43 / 1667.7 = 0.0075 \text{ } \mu\text{g/L}$$

This concentration is below the perchlorate IAL of 4 $\mu\text{g/L}$. The mixing concentrations and the overall MSC for perchlorate is presented in **Table 2**.

3.0 Summary and Conclusions

At LHAAP-35A(58), the concentrations of COCs (except perchlorate) in the groundwater are protective of surface water. The concentrations of 1,1-DCE, TCE, PCE, RDX derived using groundwater modeling at the POE at Goose Prairie Creek are either not detected or, if detected, are less than their respective MCLs or MSCs. Although the current source concentration of perchlorate at 36.9 µg/L in groundwater will result in a maximum concentration that is higher than the IAL of 4.0 µg/L at the POE (after 284 years), the mixing concentration after it is discharged into the creek will be negligible. Therefore, surface water in Goose Prairie Creek will not be adversely impacted from groundwater contamination.

Field Confirmation

The source area was assumed to be 500 ft × 600 ft and encompasses all the monitoring wells. Therefore there is no downgradient well in the lateral direction off the center line of the flow path. For this reason, no evaluation of contaminant concentration at lateral location downgradient was attempted to provide field confirmation of the model.

4.0 *References*

References are provided in the main document, Section 8.0.

Table 1
Maximum Concentrations and Chemical Properties for COCs at LHAAP-35A(58)

Chemical	Maximum Observed Concentration (µg/L)	MCL (µg/L)	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
1,1-Dichloroethene	1340.0	7.0	61.7	0.1	0.0617	6.17E-05	0.362	1.915
1,1,2-Trichloroethane	7.1	5.0	70.8	0.1	0.0708	7.08E-05	2	0.347
Trichloroethene	160.0	5.0	100.0	0.1	0.1	1.00E-04	4.5	0.154
Tetrachloroethene	5,400 ⁽⁵⁾	5.0	155.0	0.1	0.155	1.55E-04	2	0.347
Vinyl Chloride	10.0	2.0	11.0	0.1	0.011	1.10E-05	8	0.087
Bis(2-ethylhexyl)phthalate	88.3	6.0 ⁽⁶⁾	87096.0	0.1	87.096	8.71E-02	1.1	0.630
RDX ⁽³⁾	88.0	26.0 ⁽⁶⁾	195.4	0.1	0.1954	1.95E-04	N/A	N/A
Perchlorate ⁽⁴⁾	36.9	4.0 ⁽⁷⁾	N/A	---	---	---	N/A	N/A

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard et al., 1991, "Environmental Degradation Rates"

(3) Koc source: Oak Ridge National Lab Website: http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801 (RAIS); Half-life not available, assumed no degradation

(4) No data available, assumed no degradation and no water-soil partitioning

(5) Detected at LHS-MW-05 on 5/13/98. Detected at LHS-MW-05DLFD on 5/13/98 was 49010 mg/L (Jacob's Engineering Group, Inc., 2002b)

(6) msc - Texas medium specific concentration

(7) Texas interim action level

N/A not available; *

Koc carbon-water sorption coefficient

foc fraction organic carbon

Kd distribution coefficient

cm³/g cubic centimeters per gram

m³/kg cubic meters per kilogram

µg/L micrograms per liter

Table 2
Summary of 1,1-DCE, TCE, PCE, RDX and Perchlorate Concentrations
at Goose Prairie Creek (6319 feet Downgradient from Source)

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Goose Prairie (feet)	Source Release Rate* (kg/hr)	Years Contaminant Starts to Appear (years)	Maximum Concentration at POE into Goose Prairie Creek (µg/L) (DF)	MSC Based on DF at POE into Goose Prairie Creek (µg/L)	Mixing Concentration after Discharge in Goose Prairie Creek (µg/L)	Overall MSC after Discharge into Goose Prairie Creek
1,1-Dichloroethene	7.0	500 x 600	1,340	6,319	0.0246	Infinity	0 (Infinity)	Infinity	NA	NA
Trichloroethene	5.0	500 x 600	160.0	6,319	0.0029	Infinity	0 (Infinity)	Infinity	NA	NA
Tetrachloroethene	5.0	500 x 600	49,010	6,319	0.9009	Infinity	0 (Infinity)	Infinity	NA	NA
RDX	26 ⁽¹⁾	500 x 600	88.0	6,319	0.0016	134.0	12.75 (655 years) (6.9)	179.4	NA	NA
Perchlorate	4 ⁽²⁾	500 x 600	36.9	6,319	0.0007	58.0	12.43 (284 Years) (2.97)	11.9	0.0075	4920

Notes and Abbreviations:

All the sources are continuous for 6 months and extend across the entire aquifer thickness of 5 feet.

* Continuous source release rate in kg/hr = maximum source concentration x groundwater seepage velocity x source area

⁽¹⁾ msc - medium specific concentration of chemical calculated to represent less than 1e-06 cancer risk or hazard quotient less than 1.

⁽²⁾ Texas interim action level

µg/L micrograms per liter

DF dilution/attenuation factor

kg/hr kilograms per hour

MCL maximum contaminant level

MSC medium specific concentration

NA not applicable due to concentration below MCL, MSC or action level at POE

POE point of entry

Table 3
Calculation of Flow Discharge in Goose Prairie Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (feet ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.10830	0.22081	1.44906	4.88410	2.80	4.20	4.0574	20.5132	12.2853
	10 - 16	0.11651	0.30483	0.48774	2.94988	3.21	6.87	1.5656	20.2657	10.916
	17 - 23	0.06315	0.37523	0.45438	2.12994	2.10	8.56	0.9542	18.2323	9.593
	24 - 30	0.06315	0.36534	0.45438	14.99560	2.10	7.88	0.9542	118.1653	59.560
Jan-00	1 - 7	0.02700	0.36224	0.21000	7.10767	1.05	7.98	0.2205	56.7192	28.470
	8 - 14	0.12681	0.44958	0.24389	11.82963	3.45	18.63	0.8414	220.3860	110.614
	15 - 21	0.03749	0.36559	0.03032	11.51831	1.41	8.35	0.0428	96.1779	48.110
	22 - 28	0.06279	0.42399	0.80813	14.08148	2.08	17.56	1.6809	247.2708	124.476
Feb-00	1 - 7	0.09417	0.42572	0.12182	9.59478	2.65	20.51	0.3228	196.7889	98.556
	8 - 14	0.05132	0.37422	0.04973	6.47123	1.75	8.01	0.0870	51.8346	25.961
	15 - 21	0.03763	0.37675	0.04530	0.53829	1.48	9.24	0.0670	4.9738	2.520
Mar-00	22 - 28	0.14625	0.48311	0.35183	1.14280	4.45	20.51	1.5656	23.4388	12.502
	1 - 7	0.10288	0.37274	0.16989	0.50621	2.79	7.95	0.4740	4.0244	2.249
	8 - 14	0.20995	0.58798	0.48053	1.13559	6.10	21.55	2.9312	24.4720	13.702

Notes and Abbreviations:

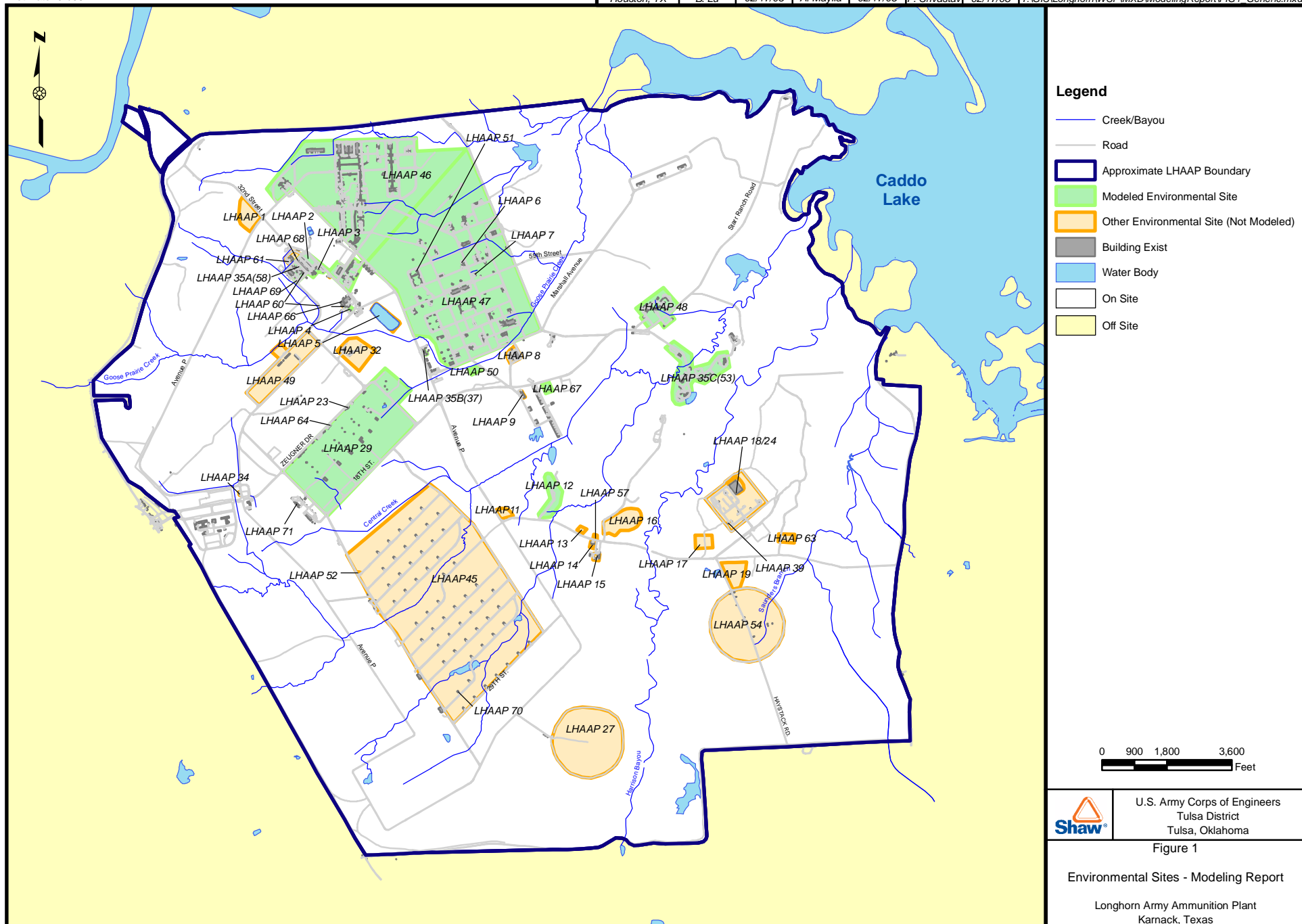
Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs cubic feet per second

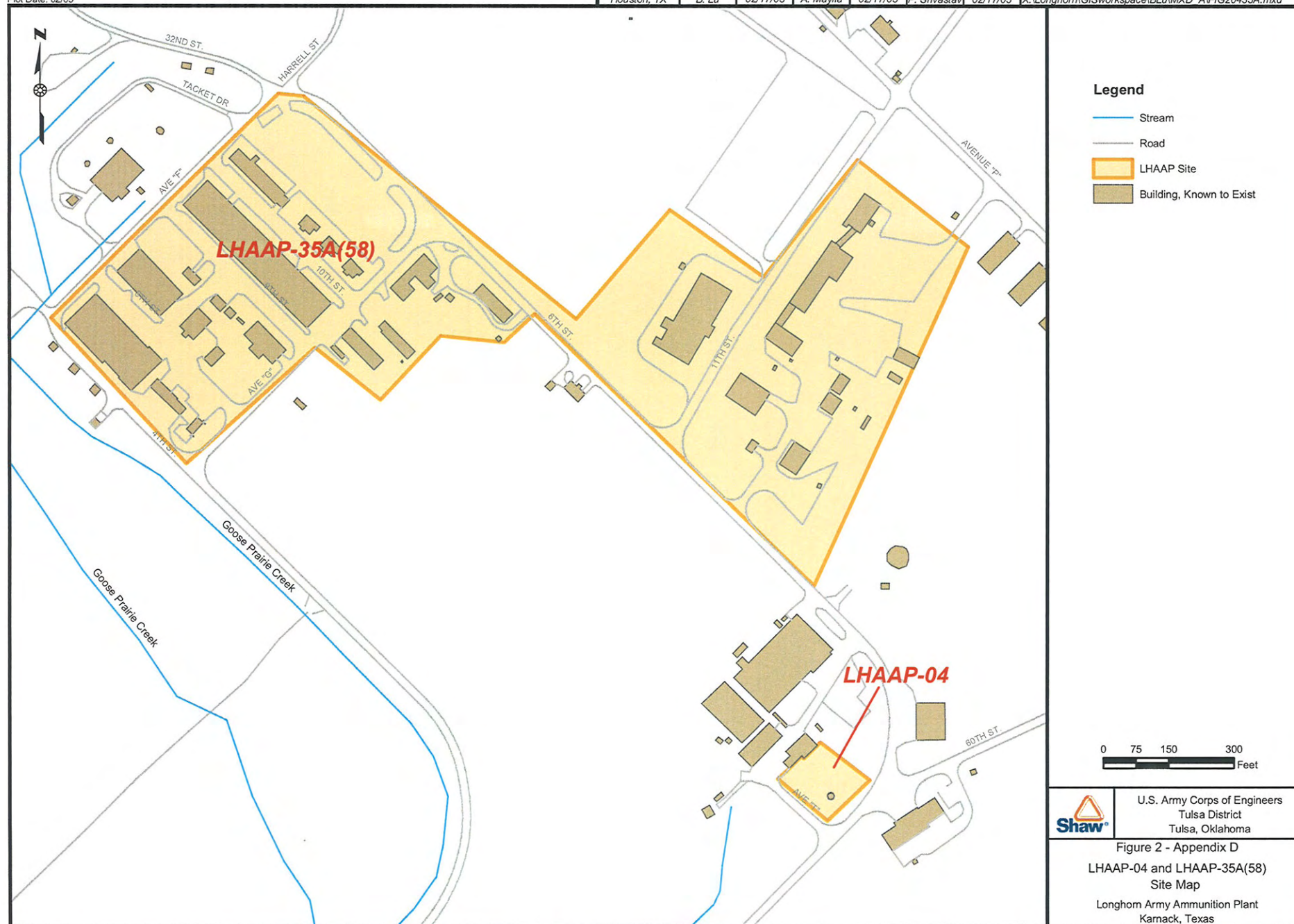
Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd



OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Lu	A. Mayila	P. Srivastav	X:\Longhorn\GIS\workspace\BLU\MXD A\FIG20435A.mxd

Plot Date: 02/05





— POTENTIOMETRIC SURFACE CONTOUR
(DECEMBER 1998 DATA)

→ GROUNDWATER POSSIBLE FLOW PATH

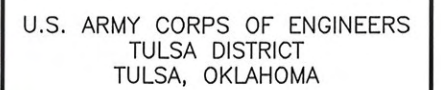
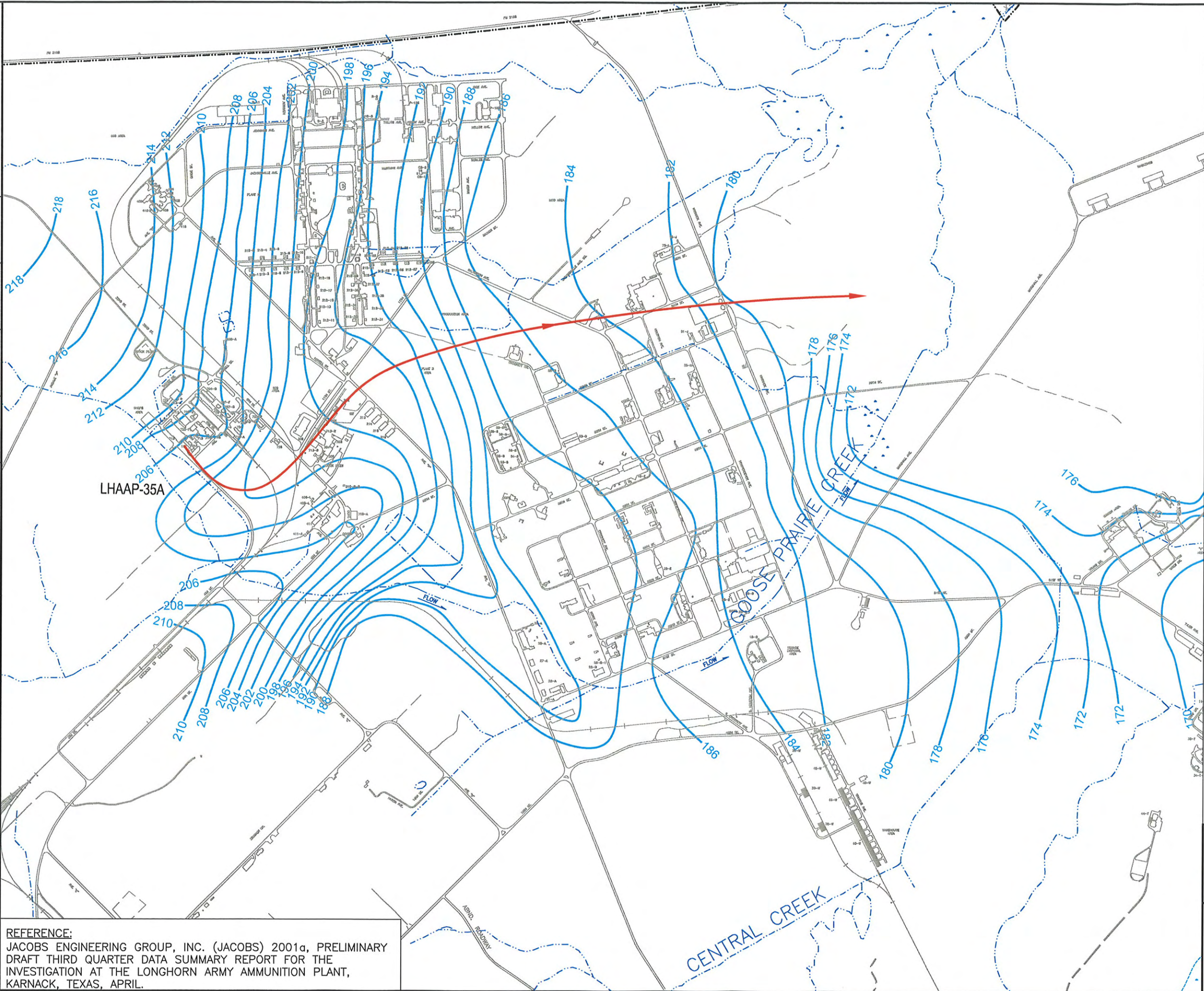


FIGURE 3A — APPENDIX D
SHALLOW GROUNDWATER ELEVATION
CONTOUR MAP (DECEMBER 1998 DATA)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



00043365

LEGEND:

POTENTIOMETRIC SURFACE CONTOUR

GROUNDWATER POSSIBLE FLOW DIRECTION

SCALE

0 1000 2000 FEET

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

FIGURE 3B – APPENDIX D
SHALLOW GROUNDWATER
ELEVATION CONTOUR MAP
(SEPTEMBER 2000 DATA)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Figure 4 - Appendix D
RDZ Concentrations in Groundwater at Goose Prairie Creek
(6319 feet from Source)
LHAAP-35A, Longhorn Army Ammunition Plant, Texas

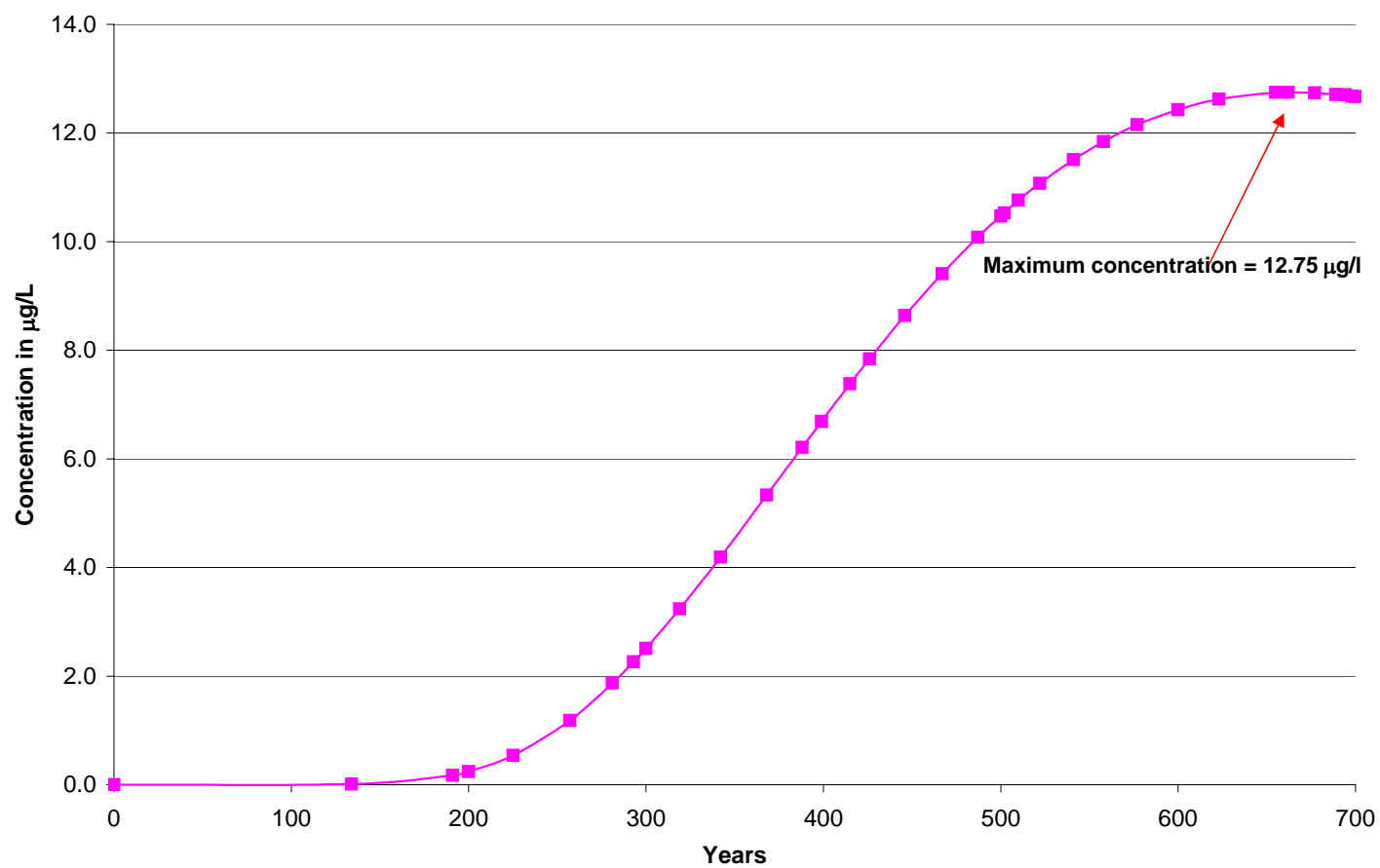


Figure 5 - Appendix D
Perchlorate Concentrations in Groundwater at Goose Prairie Creek
(6319 feet from Source)
LHAAP-35A, Longhorn Army Ammunition Plant, Texas

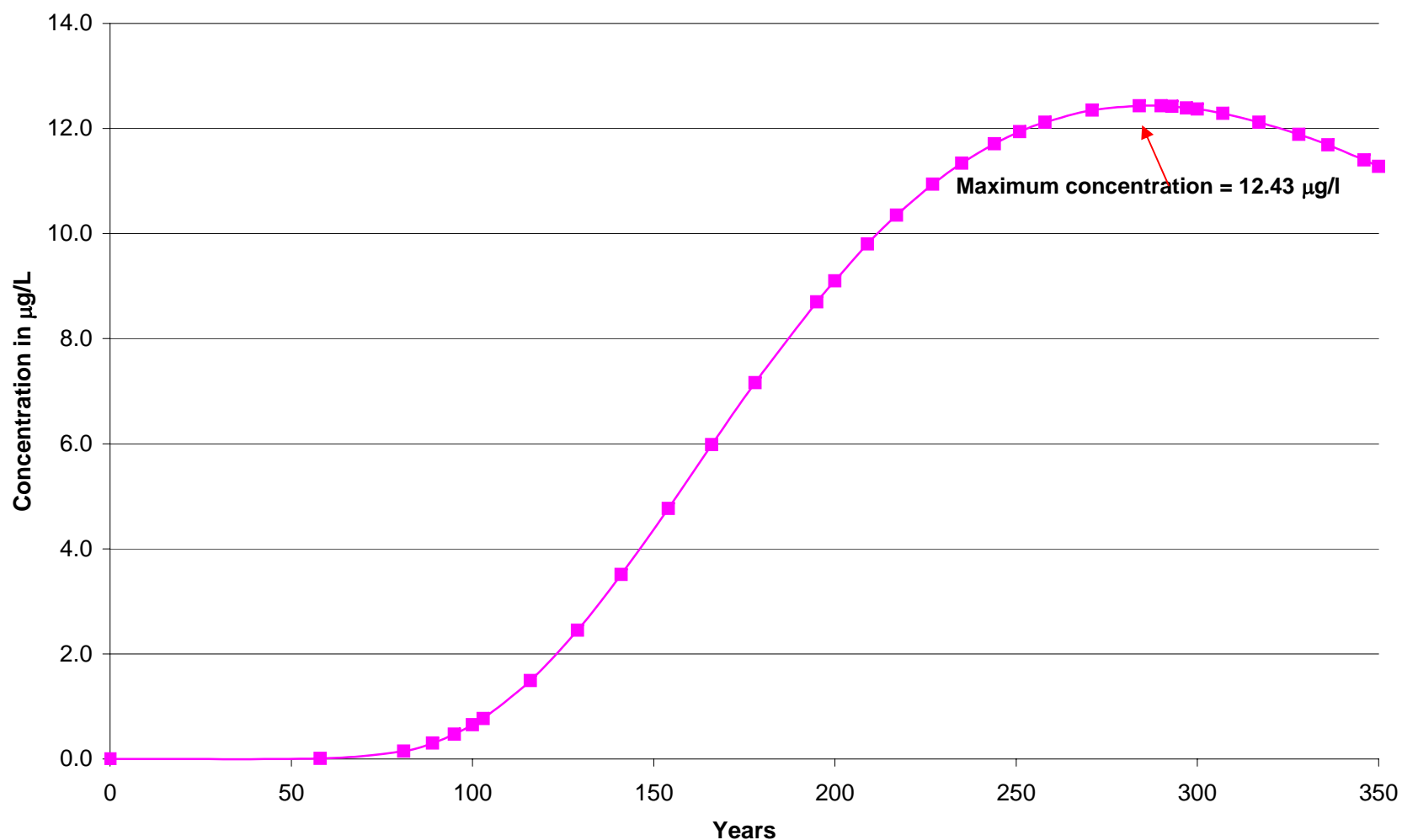
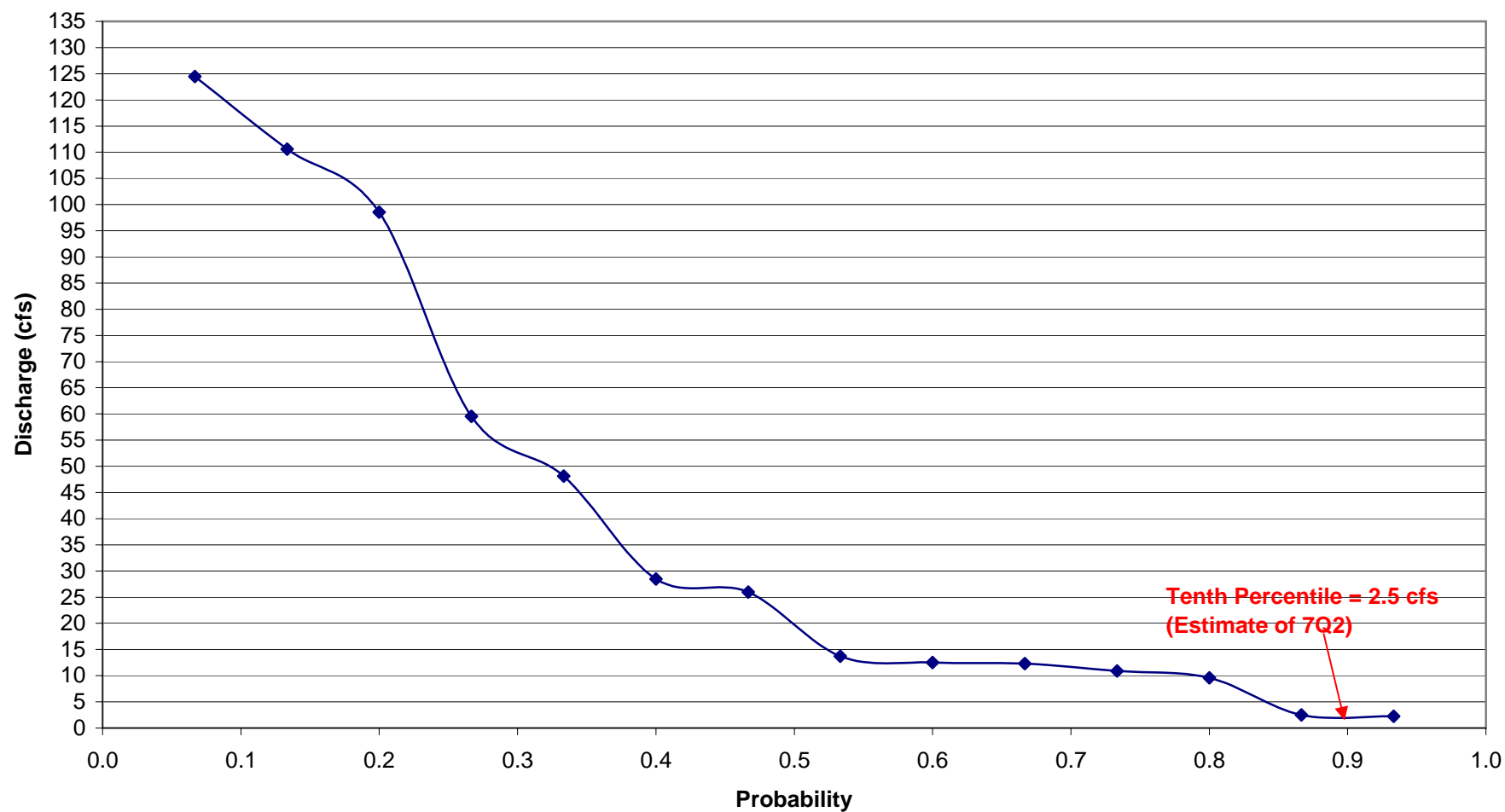


Figure 6 - Appendix D
Low Flow Analysis
Probability vs Flow Discharge for Goose Prairie Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix E

***LHAAP-35B(37) Calculation of Maximum Concentrations
and Dilution Factors of Contaminants Discharged to Goose
Prairie Creek***

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Simulation and Results	3-1
4.0	References	4-1

List of Tables

Table 1	Chemical Properties for LHAAP-35B(37) Groundwater Fate and Transport Modeling
Table 2	Summary of 1,1-DCE, TCE and PCE Concentrations at Goose Prairie Creek (125 feet Downgradient from Source)

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Simulated TCE Concentrations in Groundwater at Goose Prairie Creek

1.0 Introduction

LHAAP-35B(37) is located on the north central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-35B(37) was a chemical laboratory that used to support the production activities at the facility. The chemicals of concern in groundwater are 1,1-dichloroethene (DCE), trichloroethene (TCE), and tetrachloroethene (PCE) at maximum concentrations of 58, 330, and 34 µg/L, respectively. The chemical of concern (COCs) are at concentrations that are higher than their respective maximum contaminant levels (MCLs).

The purpose of the modeling was to calculate the maximum concentrations and dilution factors for each COC at the point of entry (POE) of the groundwater into the surface water, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the MCLs. The closest surface water body is Goose Prairie Creek. During recent data gaps investigation activities, groundwater elevations at LHAAP-35B(37) varied from 181.88 to 189.98 feet msl. Goose Prairie Creek survey data indicated that the toe of the creek is at elevations of 187.21 and 187.50 feet for location GPS. Generally, groundwater elevation underlying the site is at an elevation that is lower than Goose Prairie Creek (except for one monitoring well data) and, therefore, will not discharge into the creek. However, for conservative calculation purposes and assuming the worst-case scenario, it was assumed that groundwater discharges to Goose Prairie Creek. A table presenting groundwater and Goose Prairie Creek surface water elevations is included in Appendix M. Because of the relatively small area of LHAAP-35B(37), a potentiometric surface map was not prepared; instead, the LHAAP site-wide potentiometric map generated from the December 1998 water level measurements was utilized, which indicated that groundwater flow at the site is to the east-northeast direction (Figure 3A of Appendix A, Jacobs, 2001b). The distance from LHAAP-35B(37) to Goose Prairie Creek is approximately 125 feet (**Figure 1**).

In order to calculate the maximum concentrations of the COCs and the time of travel at the POE at Goose Prairie Creek, the computer code AT123D was used.

2.0 *Input Parameters and Assumptions*

Groundwater modeling at LHAAP-35B(37) was based on the following assumptions and considerations:

- Contaminant Source: Instantaneous source extending across the entire aquifer thickness of 13.5 feet was assumed. The only source is the current plume itself. Source contaminants consist of 1,1-DCE, TCE, and PCE with maximum concentrations of 58, 330, and 34 µg/L, respectively.
- The source area was assumed to be the plume area. The dimensions of the plume were assumed to be 350 feet (east-west) by 200 feet (north-south) by 13.5 feet in depth for all the contaminants.
- Because no geological cross section was available for this site, the geologic cross sections for LHAAP-47, an adjacent site, were used (Figures 9-3 through 9-6—Jacobs, 2002a). Based on the cross sections, the thickness of the shallow water-bearing zone consisting of sand is 13.5 feet. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 13.5 feet.
- The properties of the shallow water bearing zone used in the model were as follows:
 - Average hydraulic conductivity (K) based on the slug test at LHAAP-35B(37) was estimated to be 6.13×10^{-4} cm/sec (Jacobs, 2002a)
 - Hydraulic gradient: 0.007 feet/feet (based on the potentiometric surface map for water level measurements from December 1998) (Figure 3A –Appendix A; Jacobs, 2002a)
 - Effective porosity assumed at 0.25
 - Longitudinal groundwater dispersivity = $x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) = 12.5 ft, where x is the travel distance of contaminants, assumed to be the distance from the source to the Goose Prairie Creek = 125 feet
 - Transverse groundwater dispersivity = $\alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995) = 4.17 ft
 - Vertical groundwater dispersivity = $\alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995) = 0.625 ft

Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 1**.

3.0 *Simulation and Results*

Computer simulation results were evaluated at the POE as shown in **Table 2**. The results include the time when COCs reach the POE, the time they reach their peaks, the maximum concentrations at this location, the dilution factors and the MSC based on DF, and the action level.

Simulation shows that PCE and 1,1-DCE will not appear at detectable levels at the POE. The maximum concentration of TCE (3.63 µg/L) (**Figure 2**) at the POE is below the MCL (5 µg/L). **Table 2** lists the results of the three chemicals modeled.

Field Confirmation

In the simulation of contaminant transport, the plume area was assumed to be 350 feet × 200 feet. This area covers all the monitoring wells at the LHAAP-35B (37) site. There is no downgradient well in the lateral direction off the center line of the flow path. For this reason, no evaluation of contaminant concentration at a lateral location downgradient was attempted to provide field confirmation of the model.

4.0 *References*

References are provided in the main document, Section 8.0.

Table 1
Chemical Properties for LHAAP-35B(37) Groundwater Fate and Transport Modeling

Chemical	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
1,1-Dichloroethene	61.7	0.1	0.0617	6.17E-05	0.362	1.917
Trichloroethene	100	0.1	0.1	1.00E-04	4.5	0.154
Tetrachloroethene	155	0.1	0.155	1.55E-04	2	0.347

Notes:

Sources: (1) Montgomery, 2000, *Groundwater Chemicals - Desk Reference (Third Edition)*

(2) Howard, et al., 1991, *Environmental Degradation Rates*

Koc carbon-water sorption coefficient

foc fraction organic carbon

Kd distribution coefficient

cm³/g cubic centimeters per gram

m³/kg cubic meters per kilogram

Table 2
Summary of 1,1-DCE, TCE and PCE Concentrations
at Goose Prairie Creek (125 feet Downgradient from Source)
LHAAP-35B(37), Longhorn Army Ammunition Plant

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Goose Prairie Creek (feet)	Source Release Rate* (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration in Groundwater at Goose Prairie Creek (µg/L) (DF)	MSC Based on DF at Groundwater & Goose Prairie Creek (µg/L)
1,1-Dichloroethene	7.0	200 x 350	58	125	0.544	Never	0 (Infinity)	Infinity
Trichloroethene	5.0	200 x 350	330.0	125	3.100	2.79	3.63 (11.59 yrs) (90.9)	454.5
Tetrachloroethene	5.0	200 x 350	34	125	0.319	5.17	0.02 (6.82 yrs) (1700)	8500

Notes and Abbreviations:

All the sources are constant for 6 months and extend across the entire aquifer thickness of 13.5 feet

* Instantaneous source release in kg = maximum source concentration x plume pore volume

DF dilution/attenuation factor

kg kilograms

MCL maximum contaminant level

mg/L milligrams per Liter

MSC medium specific concentration

POE point of entry

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd

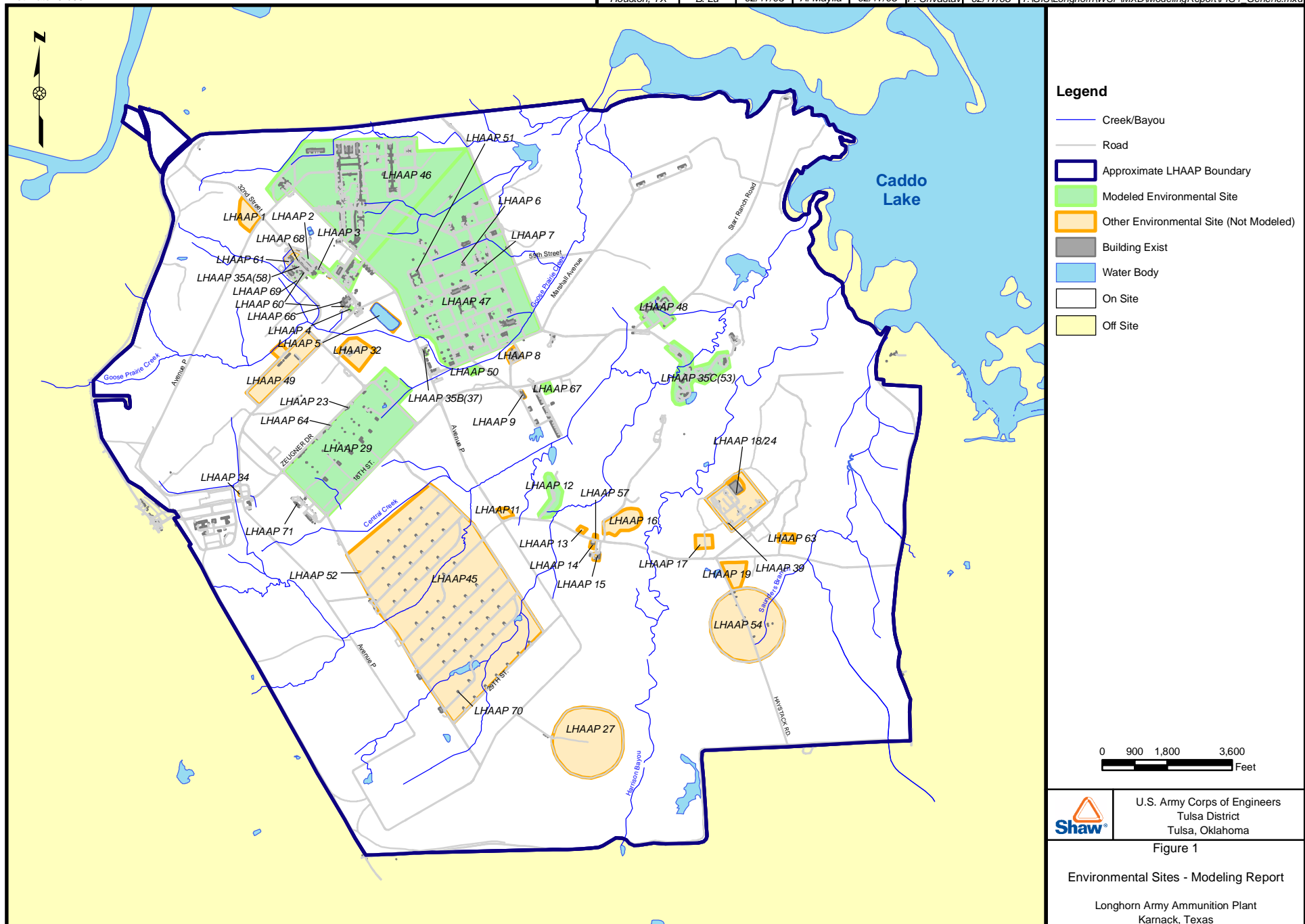
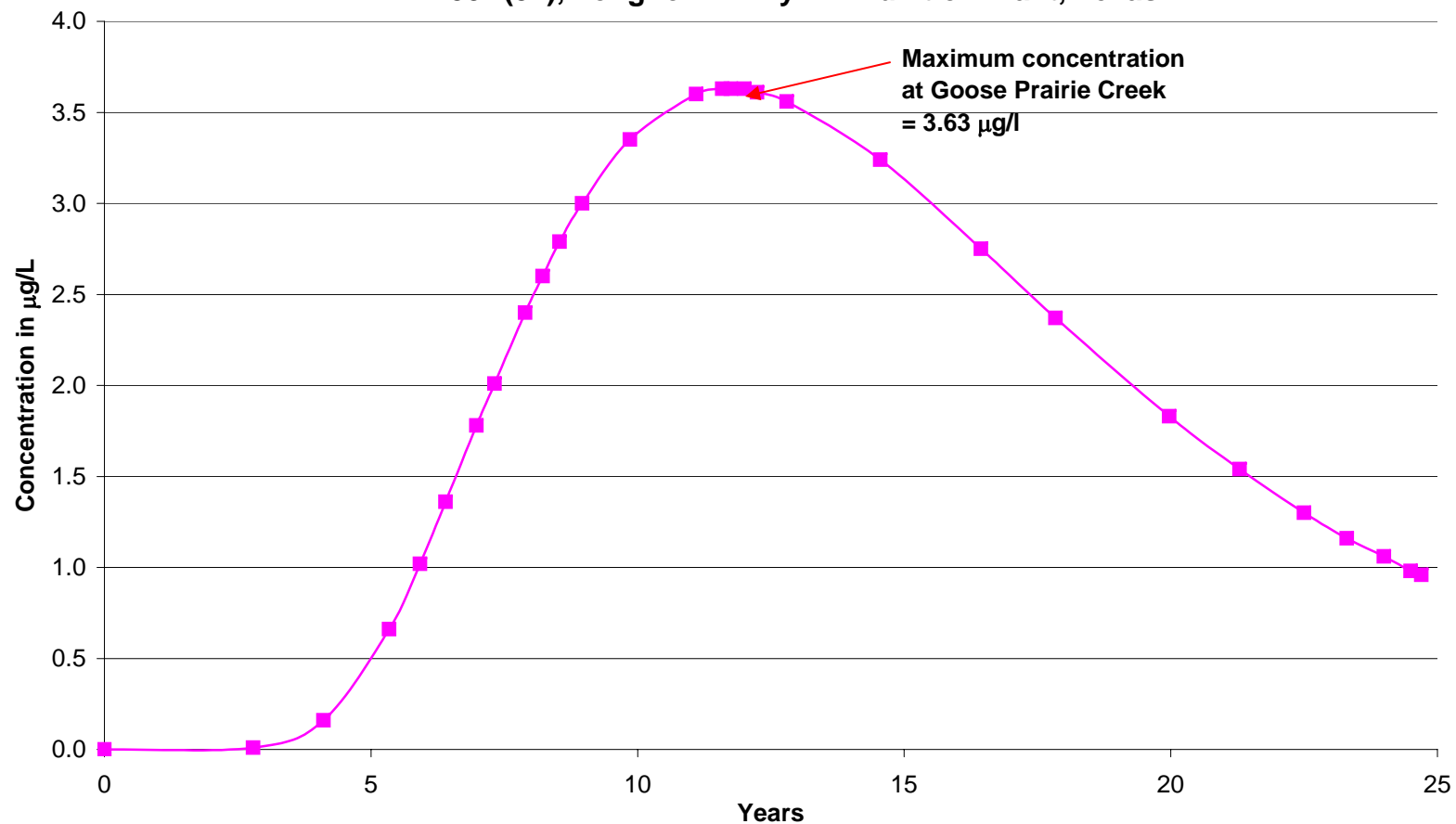


Figure 2 - Appendix E
Simulated TCE Concentrations in Groundwater
at Goose Prairie Creek
LHAAP-35B(37), Longhorn Army Ammunition Plant, Texas



Appendix F

LHAAP-35C(53) Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek or Harrison Bayou

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
2.1	Groundwater Modeling Results	2-2
3.0	Soil Concentration Protective of Sediment and Surface Water	3-1
3.1	Perchlorate Concentration in Erodable Soil Protective of Sediment	3-1
3.1.1	Soil Loss Calculation	3-1
3.1.2	Calculate ^{Sed} Soil MSC	3-3
3.2	Perchlorate Concentration in Erodable Soil Protective of Surface Water	3-4
4.0	Results	4-1
5.0	References	5-1

List of Tables

Table 1	Chemical Properties for LHAAP-35C(53) Groundwater Fate and Transport Modeling
Table 2	Summary of TCE Concentrations at Harrison Bayou and Central Creek, LHAAP-35C(53)
Table 3	Calculation of Flow Discharge in the Central Creek (Downstream)
Table 4	Rainfall/Runoff Erosivity (R Factor), Shreveport, Louisiana
Table 5	RUSLE Calculation Result for LHAAP-35C(53), Affected Area
Table 6	RUSLE Calculation Result for LHAAP-35C(53), Total Area
Table 7	Calculation of Flow Discharge in the Harrison Bayou (Downstream)

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Low Flow Analysis, Probability vs Flow Discharge for Central Creek (Downstream) Based on December 1999 to March 2000 Flow Derivation
Figure 3	Low Flow Analysis Probability vs Flow Discharge for Harrison Bayou (Downstream)

1.0 Introduction

LHAAP-35C(53) is located in the east-central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-35C(53) was a static test area. The chemicals of concern are trichloroethene (TCE) in groundwater at a maximum concentration of 7 µg/L and perchlorate in soil at a maximum concentration of 60.9 µg/kg (Jacobs, 2000a). TCE is at a concentration that is higher than its maximum contaminant levels (MCLs) and perchlorate in soil may impact other media in time.

There are two streams in the vicinity of LHAAP-35C(53): Central Creek to the northwest and Harrison Bayou to the southeast. Contaminants in groundwater are likely to travel to Harrison Bayou rather than to Central Creek due to the southerly groundwater flow from LHAAP-35C(53) based on the September 2000 potentiometric surface map (Figure 3B in Appendix A; Jacobs, 2002a). The distance from LHAAP-35C(53) to Central Creek and Harrison Bayou is approximately 300 and 658 feet, respectively (**Figure 1**).

The purpose of the modeling is to calculate the maximum concentrations and dilution factors for TCE at the point of entry (POE) into Central Creek and Harrison Bayou, and, if necessary, after discharge into the surface water. The purpose is also to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the MCL. Calculations were also performed to develop surface perchlorate soil concentrations protective of sediment and surface water due to the erosion of soil by storm-generated runoff to the nearby surface water body. Because of the low levels of perchlorate in soil at a maximum concentration of 60.9 µg/kg, transport through the vadose zone to groundwater and from groundwater to surface water was not modeled. It is anticipated that perchlorate in the soil will not affect groundwater and surface water adversely. This is supported by the results obtained at a similar site, LHAAP-04. At LHAAP-04, the maximum perchlorate concentration in top soil was 163,000 µg/kg. Modeling results at LHAAP-04 indicated that even at this elevated perchlorate level, surface water was not adversely affected and the resultant concentration in surface water was below the interim action limit of 4 µg/L. However, evaluation of perchlorate soil concentrations protective of sediment and surface water via erosion and transport were performed.

In order to calculate the maximum concentrations of the TCE and the time of travel at the POE at Central Creek and Harrison Bayou, the computer code AT123D was used.

2.0 *Input Parameters and Assumptions*

Groundwater modeling at LHAAP-35C(53) was based on the following assumptions and considerations:

- Contaminant Source: No continuous source in the upper layer, only instantaneous source was assumed. The only source is the current plume itself with a maximum concentration of 7 µg/L.
- The source area was assumed to be the plume area. The dimension of the plume was assumed to be 100 feet (east-west) by 100 feet (north-south) for TCE estimated from the sampling locations where TCE was detected (Jacobs, 2000a)..
- Because cross sections were not available for LHAAP-35C(53), the average well screen length that covers sand, silty clay and silty sand was used. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 11 feet.
- The properties of the shallow water bearing zone used in the model were as follows:
 - Average hydraulic conductivity (K) based on the slug tests at LHAAP-35C(53) was estimated to be 6.9×10^{-4} cm/sec (Jacobs, 2002a)
 - Hydraulic gradient: 0.007 feet/feet (based on the potentiometric surface map for water level measurements in September 2000, Jacobs, 2002a)
 - Effective porosity assumed at 0.25
 - Longitudinal groundwater dispersivity: $= x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) where x is the travel distance of contaminants, assumed to be the distance from the source to the Central Creek = 30 feet; to Harrison Bayou = 65.8 feet.
 - Transverse groundwater dispersivity: $= \alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995) = 10 feet (Central Creek); = 21.9 feet (Harrison Bayou).
 - Vertical groundwater dispersivity: $= \alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995) = 1.5 feet (Central Creek); = 3.29 feet (Harrison Bayou).

Chemical property of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 1**. Other input parameters and simulation results are shown in **Table 2**. Simulation results show that TCE will not reach Harrison Bayou and will reach Central Creek at a very low concentration of 0.14 µg/L in groundwater. Because of the low levels of perchlorate in soil at a maximum concentration of 60.9 µg/kg, transport through the vadose zone to groundwater and from groundwater to surface water was not modeled. It is anticipated that perchlorate in the soil will not impact groundwater and surface water adversely. This is supported by the results obtained at a similar site, LHAAP-04. At LHAAP-04, the maximum perchlorate concentration in top soil was 163,000 µg/kg.

2.1 *Groundwater Modeling Results*

Modeling results at LHAAP-04 indicated that even at this elevated perchlorate level, surface water was not adversely impacted and resultant concentration in the surface water was below the interim action limit of 4 µg/L. However, evaluation of perchlorate soil concentrations protective of sediment and surface water via erosion and transport had to be performed.

Field Confirmation

The source plume of TCE at this site was assumed conservatively to cover an area of 100 ft x 100 ft. TCE's maximum concentration of only 7 µg/L was detected at well LHSMW67. No downgradient wells are in the downgradient direction towards Central Creek or Harrison Bayou. For this reason, no evaluation of contaminant concentration at a lateral location downgradient was attempted to provide field confirmation of the model.

3.0 *Soil Concentration Protective of Sediment and Surface Water*

Perchlorate in the subsurface soil, together with the contaminated soil particles will be transported by storm-generated runoff to nearby surface water bodies – in this case Central Creek or Harrison Bayou. Since the distance from the source to Harrison Bayou is longer than to Central Creek by approximately 360 feet more, the shortest distance was conservatively assumed to be the distance for the eroded contaminated soil to travel to the nearest stream, Central Creek, which is 300 feet from the source area.

The approach to develop surface soil concentrations protective of sediment and surface water is described in the main volume of this report and in the following sections.

3.1 *Perchlorate Concentration in Erodable Soil Protective of Sediment*

A screening calculation was performed to evaluate whether storm water from an affected property has the potential to pose a risk to human or ecological receptors in the Central Creek. First, soil loss from the effected property was evaluated by the revised universal soil loss equation (RUSLE) before soil concentration protective of sediment could be calculated.

3.1.1 *Soil Loss Calculation*

The RUSLE is in the form:

$$A = R \times K \times L \times S \times C \times P \quad \text{Equation F1}$$

Where :

- A = Estimated average annual soil loss (ton/ac-yr)
- R = Rainfall-runoff erosivity factor (feet-ton-in/ac-hr-yr)
- K = Soil erodibility (ton/ac per unit of R)
- L = Slope length factor (unitless)
- S = Slope steepness factor (unitless)
- C = Cover management factor (unitless)
- P = Support practice factor (unitless)

The input parameters are all depend on the location of the site being evaluated. The location factor actually implicitly describes rainfall, land use, surface coverage, soil type and other factors in that location. Since LHAAP is close to Shreveport, Louisiana, some of the parameters established for Shreveport were used for LHAAP as described below.

- **Rainfall-runoff erosivity factor (R).** When the factors other than rainfall are held constant, soil losses from cultivated land are directly proportional to a rainstorm parameter: total storm energy (E) multiplied by the maximum 30-minute intensity (I).

R was obtained using RUSLE software. The topographic slope in the affected area as well as the slope from LHAAP-35C(53) to Central Creek (total area) was estimated to be 0.4 percent. The overall *R* value of 400 was thus given in the template provided by the RUSLE program. **Table 4** shows the annual precipitation of 43.8 inches with monthly distributions of rainfall and temperature for the city of Shreveport. Hourly *EI* distribution is also presented. The *R* factor was estimated and also presented in this template.

- **Soil erodibility (*K*).** The *K* factor is the ease with which soil is detached by splash during rainfall or by surface flow or by a combination of both. It is a function of the composition of soil type, percentage of organic matter, soil structure and grain size, and soil permeability. In this current evaluation, it was assumed that the topsoil consists of 29 percent silt and very fine sand, 70 percent clay, 1 percent organic matter, medium to coarse granular (less than 5 mm), and low permeability. The result of *K* factor, using these soil properties in a nomograph, is 0.14 and 0.19, respectively for the affected area and the total area as shown in **Tables 5 and 6**, which is the soil loss and sediment yield computation worksheet.
- **Topographic factor, including *L* and *S* (*LS*).** The value of *LS* increases as hill slope length and steepness increase. In this calculation, only one single segment of slope was assumed. Soil texture and land use were assumed as silty clay and “disturbed topsoil, rock cover.” “Rock cover” was assumed to represent pavement and construction with impervious cover. The calculated *LS* values are 0.08 for both the affected area and the total area, respectively, as shown in **Tables 5 and 6**.
- **Cover management factor (*C*).** The *C* factor is the ratio of soil loss with specific cropping and management practices to the corresponding loss with up-slope and down-slope tillage and continuously fallow conditions. The calculated values of *C* are 0.12 (affected area) and 0.14 (total area) as shown in **Tables 5 and 6**.
- **Support practice factor (*P*).** The *P* factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing on soil loss at a particular site. The *P* factor was calculated through the RUSLE equations and the results are 0.82 and 0.98 respectively for the affected area and the total area as shown in **Tables 5 and 6**.

The resultant soil losses calculated using the RUSLE program are 0.4 tons/ac-yr for the affected area and 0.82 tons/ac-yr for the total area.

In moving towards the outlet, soil will be trapped by vegetation and plant residue or will be deposited in low lying areas, local scour, rills and channels. Other factors that inhibit the eroded material’s delivery to the watershed outlet include climate, soil particle size and texture, size and proximity of the upland erosion source, the ratio of rill versus sheet erosion, total watershed area, watershed length and relief, and drainage density. Therefore, not all of the soil loss calculated by the above approach will reach the watershed outlet. The sediment yield or load at the outlet should be estimated using a sediment delivery ratio (SDR) from 0 to 1 to account for the

deduction factors. RUSLE is designed in calculating the SDR by assigning different values for permanent barriers (strips or concaves) and terraces or sediment basins that include the land slope, soil type and texture, etc. Because many of the site-specific data are not available, assumptions were made, similar to the assumptions described in the previous sections. The SDR values estimated using RUSLE are 0.74 (affected area) and 0.92 (total area) as shown in **Tables 5 and 6**.

The annual sediment yields calculated using RUSLE are 0.4 tons/ac-yr for the affected area and 0.82 tons/ac-yr for the total area (**Tables 5 and 6**).

3.1.2 Calculate ^{Sed}Soil MSC

The soil concentration protective of sediment, ^{Sed}Soil MSC (or C_{AP}), is calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT}) - (SL_{OA} \times C_{OA})}{SL_{AP}} \quad \text{Equation F2}$$

where:

- C_{AP} = the ^{Sed}Soil MSC (mg/kg) for the surface water runoff pathway from the affected area
- SL_{TOT} = total sediment load estimated for the entire contributing watershed. (0.82 tons/ac-yr = 820 kg/ac-yr, see **Section 3.1.1**).
- C_{TOT} = published regulatory standard for COC (mg/kg)
- SL_{OA} = sediment load (kg/yr) estimated for other areas of the watershed
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds. Because there is no Texas-specific median background soil concentrations, $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area
- SL_{AP} = sediment load (kg/yr) from the affected property. In this case, 0.4 tons/ac-yr = 400 kg/ac-yr.

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT})}{SL_{AP}} \quad \text{Equation F3}$$

where:

- SL_{TOT} = 820 kg/ac-yr
- SL_{AP} = 400 kg/ac-yr
- C_{TOT} = 25 mg/kg (sediment PCL for perchlorate for human risk, Table for Risk Reduction Program Rule, TNRC, 2002)

Therefore, C_{AP} (^{Sed}Soil MSC) = (820)(25)/400 = 51.3 mg/kg.

Note that perchlorate concentration in soil at the source that can be eroded is 0.061 mg/kg, which is smaller than ^{Sed}Soil MSC (= 51.3 mg/kg).

3.2 Perchlorate Concentration in Erodable Soil Protective of Surface Water

In this study, it was assumed conservatively that 7Q2 conditions in Central Creek (flow in 7 consecutive days occurs once every 2 years) prevail and therefore have a greater effect on the creek after mixing and dilution. However, the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 2.5 cubic feet per second (cfs) is derived (**Figure 2**). Because site LHAAP-35C (53) is situated closer to the downstream side of the Central Creek, flow data at the downstream cross section were used.

The equation used to estimate the COC concentration in runoff from the affected property is as follows (TCEQ, 2002):

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation F4}$$

where:

- C_{AP} = concentration of perchlorate in runoff from the affected property (mg/L)
- Q_D = flow downstream of the affected property watershed (feet³/sec), using 7Q2 flow
- C_D = concentration of perchlorate downstream of the affected property (mg/L)
- Q_{AP} = runoff from the affected property (feet³/sec)
- Q_{OA} = runoff from other areas of the affected property watershed (feet³/sec)
- C_{OA} = concentration of perchlorate in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U) \quad \text{Equation F5}$$

where:

- R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
- I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated using the following equation (feet³/sec):

$$Q = P \times P_J \times R_{VU} \times A_U \quad \text{Equation F6}$$

where:

- P = precipitation rate (inches/year)
- P_J = ratio of storms producing runoff (unit less) with a default value of 0.9
- R_{VU} = runoff coefficient (unit less) for land use type U (inches_{run}/inches_{rain})
- A_U = area of land use type u (acres)

At LHAAP-35C(53), the affected property is estimated to be 0.00918 acres (20 feet x 20 feet). The annual precipitation at LHAAP is estimated to be 45 inches/year (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 50 percent and 10 percent, respectively. Therefore,

For the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.6)](0.00918)\} = 0.02 \text{ feet}^3/\text{sec}$$

Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and therefore the other areas of the affected property watershed are omitted.

$$Q_D = 1.75 \text{ feet}^3/\text{sec} \quad (\text{Based on 7Q2 flow data included in Table 3 and Figure 2})$$

The concentration of perchlorate in the solute, $Conc_{source}$ (mg/L), can be derived from the soil concentration of 0.0609 mg/kg, $Conc_{soil}$ (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation F7}$$

where:

- ρ_b = bulk density of soil = assumed 1.7 g /cm³
- k_d = distribution coefficient = Assumed 0.0 cm³/g
- ϕ_w = water-filled porosity = 0.35
- ϕ_a = air-filled porosity = assumed 0.15
- H_c = Henry's law coefficient = assumed 0.0 (dimensionless)

$$Conc_{source} = \frac{0.061 \times 1.7}{(0.35 + 0.0 \times 0.15)} = 0.296 \text{ mg/L}$$

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.02)(0.296)/1.75 = 0.0034 \text{ mg/L} = 3.4 \text{ } \mu\text{g/L}$$

This concentration ($C_D = 3.4 \mu\text{g/L}$) is less than the interim action level (IAL) of $4 \mu\text{g/L}$ for perchlorate in surface water.

When perchlorate concentration downstream of the affected property (C_D) is set equal to the IAL of $4 \mu\text{g/L}$, the resulting C_{AP} represents the risk-based perchlorate concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (1.75)(4)/(0.02) = 350 \mu\text{g/L}$$

Using the equation shown below, perchlorate concentration in soil (C_{soil}) can be derived by:

$$C_{\text{soil}} = \frac{[\phi_w + H_c \phi_a] C_{AP}}{\rho_b} = [0.35 + 0.0(0.15)](350)/1.7 = 72 \mu\text{g/kg}$$

This value C_{soil} ($=^{\text{SW}}\text{Soil MSC}$); i.e., soil concentration protective of surface water is greater than the actual perchlorate concentration of $60.9 \mu\text{g/kg}$ at the source.

4.0 Results

Simulation shows that TCE will not exceed its MCL of 5 µg/L at the POE in groundwater at Central Creek or Harrison Bayou. Even if the maximum concentration of TCE is placed at the two creeks, Central Creek and Harrison Bayou, the mixing concentrations in the creeks at 4.2×10^{-5} and 7.9×10^{-4} µg/L, respectively, are much lower than the MCL (see **Table 2**). These concentrations were calculated based on the seepage flow out into the streams from groundwater and the flow discharge in the streams based on the 10th percentile flow of 1.75 cfs in Central Creek and 19 cfs in Harrison Bayou (see **Table 7** and **Figure 3**). In the case of perchlorate, it is anticipated that its maximum concentration at the surface water (both creeks) will not exceed its IAL of 4 µg/L when it reaches the surface water through leaching from soil and via groundwater to surface water, based on similar calculations conducted at other sites (e.g., LHAAP-04). The current maximum concentration of 60.9 µg/kg in soil will also be protective of sediment and surface water.

5.0 References

References are provided in the main document, Section 8.0.

Table 1
Chemical Properties for LHAAP-35C (53) Groundwater Fate and Transport Modeling

Chemical	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
Trichloroethene	100	0.1	0.1	1.00E-04	4.5	0.154

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard et al., 1991, "Environmental Degradation Rates"

cm³/g cubic centimeters per gram

foc fraction organic carbon

Kd water-soil partition coefficient

Koc carbon-water sorption coefficient

m³/kg cubic meters per gram

Table 2
Summary of TCE Concentrations
at Harrison Bayou and Central Creek
LHAAP-35C (53), Longhorn Army Ammunition Plant

Harrison Bayou

Source Type	MCL	Source Area (north-south x east-west)	Maximum Observed Source Concentration	Distance to Harrison Bayou	Source Release Rate*	Years Contaminant Starts to Appear (years)	Maximum Concentration in Groundwater at POE at Harrison Bayou (µg/L) (DF)	MSC Based on DF at Groundwater & Harrison Bayou	Mixing Concentration in Harrison Bayou	Overall MSC after Discharge into Harrison Bayou
	(µg/L)	(feet x feet)	(µg/L)	(feet)	(kg)			(µg/L)	(µg/L)	(µg/L)
Trichloroethene	5.0	100 x 100	7.0	658	0.008	Never	0 (Infinity)	Infinity	NA	NA

Central Creek

Source Type	MCL	Source Area (north-south x east-west)	Maximum Observed Source Concentration	Distance to Central Creek Creek	Source Release Rate*	Years Contaminant Starts to Appear (years)	Maximum Concentration in Groundwater at POE at Central Creek (µg/L) (DF)	MSC Based on DF at Groundwater & Central Creek	Mixing Concentration in Central Creek	Overall MSC after Discharge into Central Creek
	(µg/L)	(feet x feet)	(µg/L)	(feet)	(kg)			(µg/L)	(µg/L)	(µg/L)
Trichloroethene	5.0	100 x 100	7.0	300	0.008	4	0.14 (10 yrs) (50)	250	NA	NA

Assumed Source at Harrison Bayou and Central Creek

Source Type	MCL	Source Area (north-south x east-west)	Maximum Observed Source Concentration	Distance to Harrison Bayou or Central Creek	Source Release Rate*	Years Contaminant Starts to Appear (years)	Maximum Concentration in Groundwater at Harrison Bayou & Central Creek POE (µg/L)	MSC Based on DF at Groundwater & Harrison Bayou or Central Creek (µg/L)	Mixing Concentration in Harrison Bayou & Central Creek (µg/L)	Overall MSC after Discharge into Harrison Bayou or Central Creek (µg/L)
	(µg/L)	(feet x feet)	(µg/L)	(feet)	(kg)			(µg/L)	(µg/L)	(µg/L)
Trichloroethene	5.0	100 x 100	7.0	0	0.008	Instant	7.0	5.0	4.2 x 10 ⁻⁵ (HB) 7.9 x 10 ⁻⁴ (CC)	166,667 (HB) 8,861 (CC)

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 11 feet.
 * Instantaneous source release in kg = maximum source concentration x plume pore volume
 DF dilution/attenuation factor
 HB Harrison Bayou; CC = Central Creek
 MSC medium specific concentration
 NA not analyzed or not applicable
 POE point of entry

Table 3
Calculation of Flow Discharge in the Central Creek (downstream)
(Data Collected from Dec 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth	Measured Velocity	Cross Sectional Area	Calculated Discharge
		(ft)	(ft/s)	(ft ²)	(cfs)
		Downstream	Downstream	Downstream	Downstream
Dec-99	3 - 9	1.11074	1.29100	6.31	8.1462
	10 - 16	1.48660	0.25542	7.30	1.8646
	17 - 23	1.46344	0.73705	7.25	5.3436
	24 - 30	1.32520	0.23729	7.00	1.6610
Jan-00	1 - 7	1.06090	0.29642	11.90	3.5274
	8 - 14	1.62076	0.19877	10.80	2.1467
	15 - 21	1.48365	0.15027	7.20	1.0819
	22 - 28	1.36087	3.31644	11.00	36.4808
Feb-00	1 - 7	1.63820	0.54047	6.12	3.3077
	8 - 14	1.51571	0.25153	11.70	2.9429
	15 - 21	1.44892	1.64454	7.26	11.9394
	22 - 28	1.55024	0.25240	7.15	1.8047
Mar-00	1 - 7	2.07625	3.62250	17.90	64.8428
	8 - 14	2.40898	2.59353	25.30	65.6163

Notes and Abbreviation:

Measured depths and measured velocities are averaged values over every seven days
Cross sectional areas are based on the measured depths and cross sections

cfs = cubic feet per second

Table 4
Rainfall/Runoff Erosivity (R Factor)
Shreveport, Louisiana

City code: 18003	City: Shreveport	State: LA	
Total P: 43.8 "	El curve #: 96	Freeze-Free days/year: 272	
Elevation (ft): 252	10 yr El: 180	R factor: 400	
Mean P (")	Tave (deg. F)	%EI	%EI
4.02	47.8	0	54
3.46	51.7	2	58
3.77	58.15	4	62
4.71	67.05	6	66
4.7	73.7	9	70
3.54	81.2	12	74
3.56	83.45	17	78
2.52	84.15	23	82
3.29	78.75	30	86
2.63	68.45	37	90
3.77	56.25	43	94
3.87	49.8	49	97

Table 5
RUSLE Calculation Result for LHAAP-35C (53) – Affected Area

	R	K	LS	C	[P	SDR]	A	SY
SITE35CA	400	0.14	0.08	0.12	0.82	0.74	.45	0.4
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes:

Annual sediment yield: 1.2 tons/ac-yr

A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Table 6
RUSLE Calculation Result for LHAAP-35C (53) – Total Area

	R	K	LS	C	[P	SDR]	A	SY
S35CALL	400	0.19	0.08	0.14	0.977	0.92	.88	0.82
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes:

Annual sediment yield: 1.2 tons/ac-yr
A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Table 7
Calculation of Flow Discharge in the Harrison Bayou (Downstream)
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)	Measured Velocity (feet/second)	Cross Sectional Area (square feet)	Calculated Discharge (cfs)
		Downstream	Downstream	Downstream	Downstream
Dec-99	3 - 9	3.37480	0.30440	105.00	31.9620
	10 - 16	3.69160	0.34860	128.00	44.6208
	17 - 23	3.27500	0.11400	98.00	11.1720
	24 - 30	3.20430	0.35050	90.00	31.5450
Jan-00	1 - 7	3.30580	0.35250	99.00	34.8975
	8 - 14	3.98980	0.29030	148.00	42.9644
	15 - 21	3.42900	0.23540	112.00	26.3648
	22 - 28	3.62910	0.19780	122.00	24.1316
Feb-00	1 - 7	3.99540	0.56400	150.00	84.6000
	8 - 14	3.68440	0.93390	127.50	119.0723
	15 - 21	3.60140	0.13790	120.00	16.5480
	22 - 28	3.90640	0.33230	143.00	47.5189
Mar-00	1 - 7	3.77690	0.15670	135.00	21.1545
	8 - 14	3.92540	0.19900	146.00	29.0540

Notes:

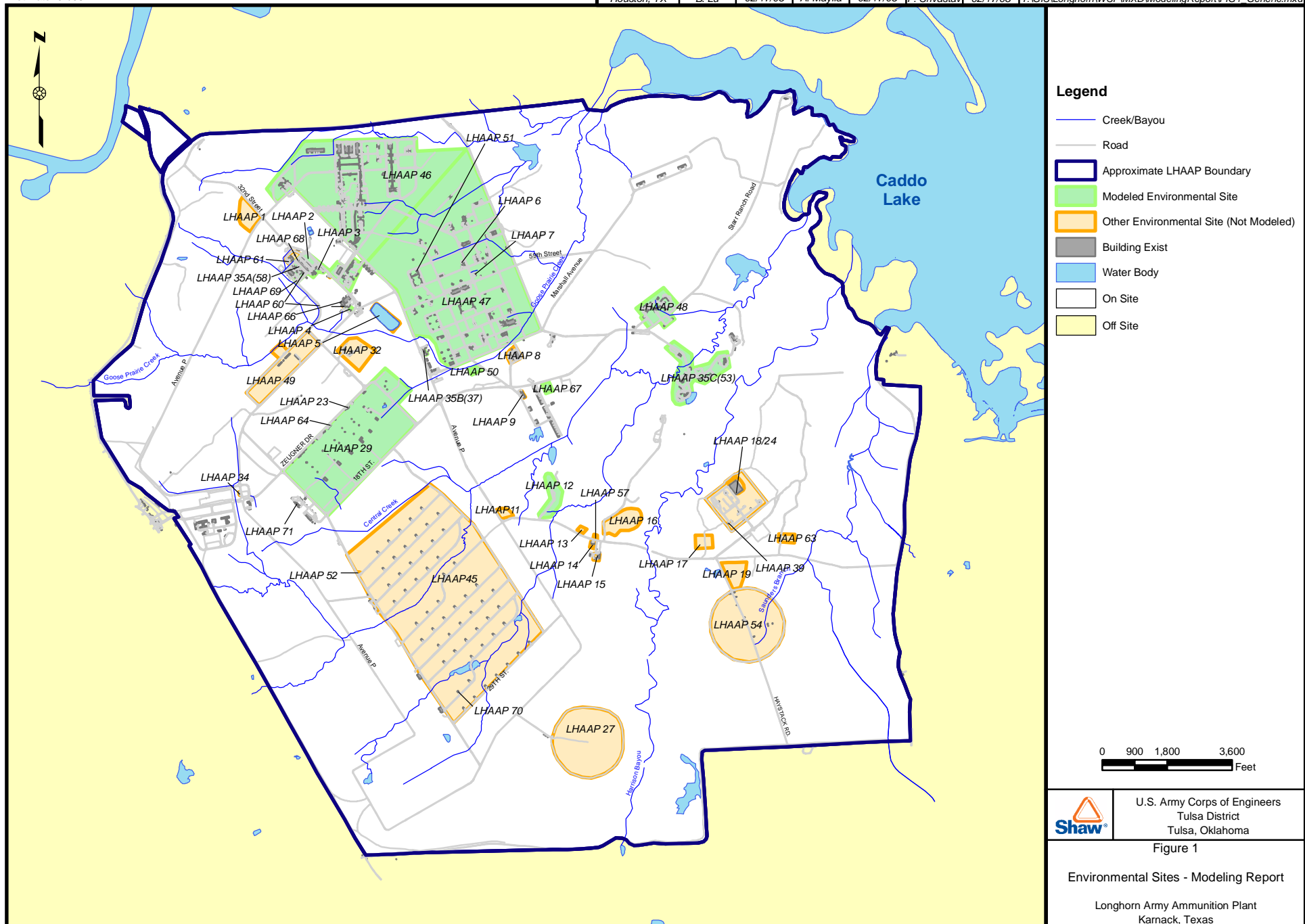
Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs = cubic feet per second

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd



U.S. Army Corps of Engineers
Tulsa District
Tulsa, Oklahoma

Figure 1

Environmental Sites - Modeling Report

Longhorn Army Ammunition Plant
Karnack, Texas

Figure 2 - Appendix F
Low Flow Analysis
Probability vs Flow Discharge for Central Creek (Downstream)
Based on December 1999 to March 2000 Flow Derivation

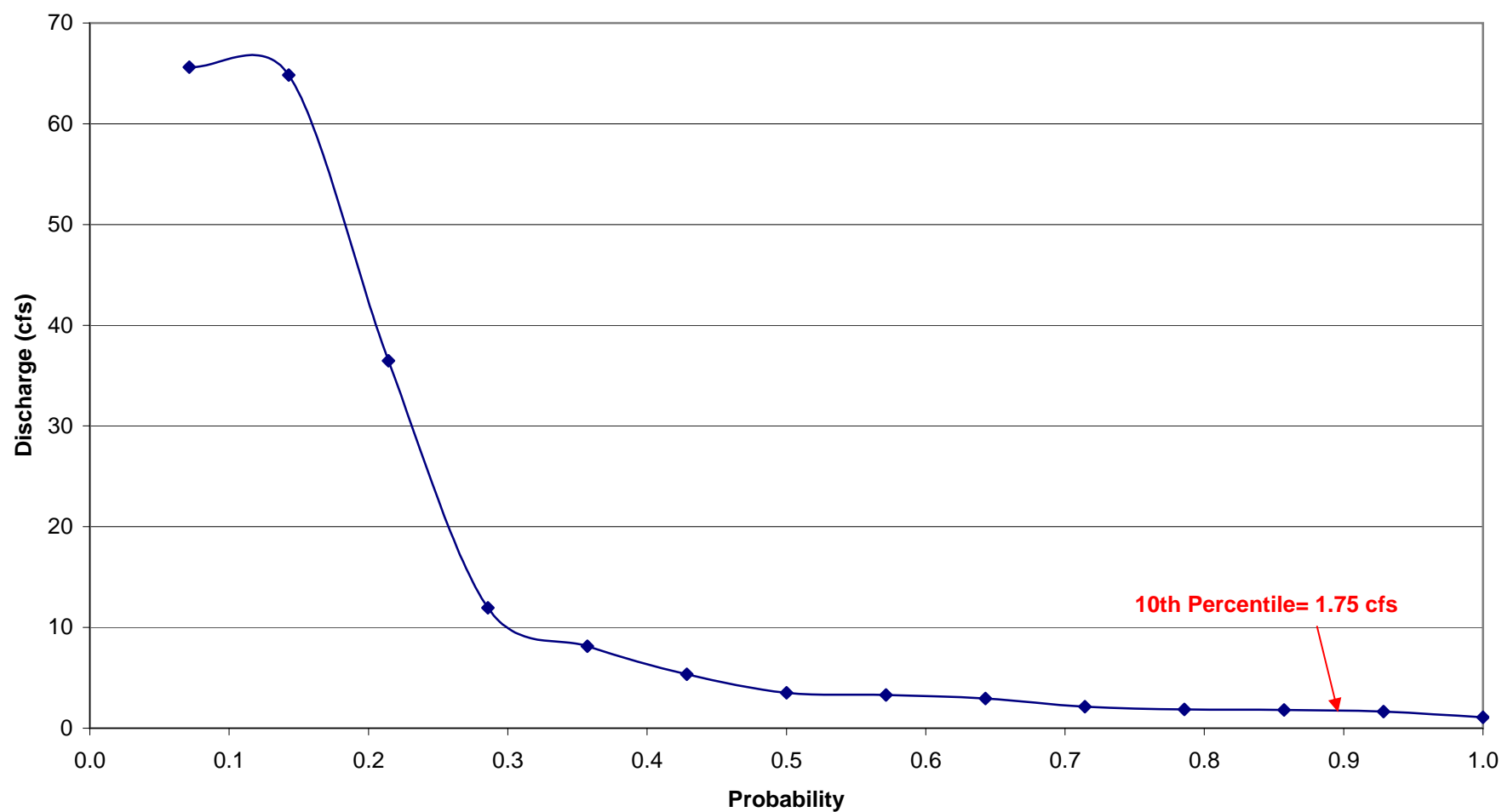
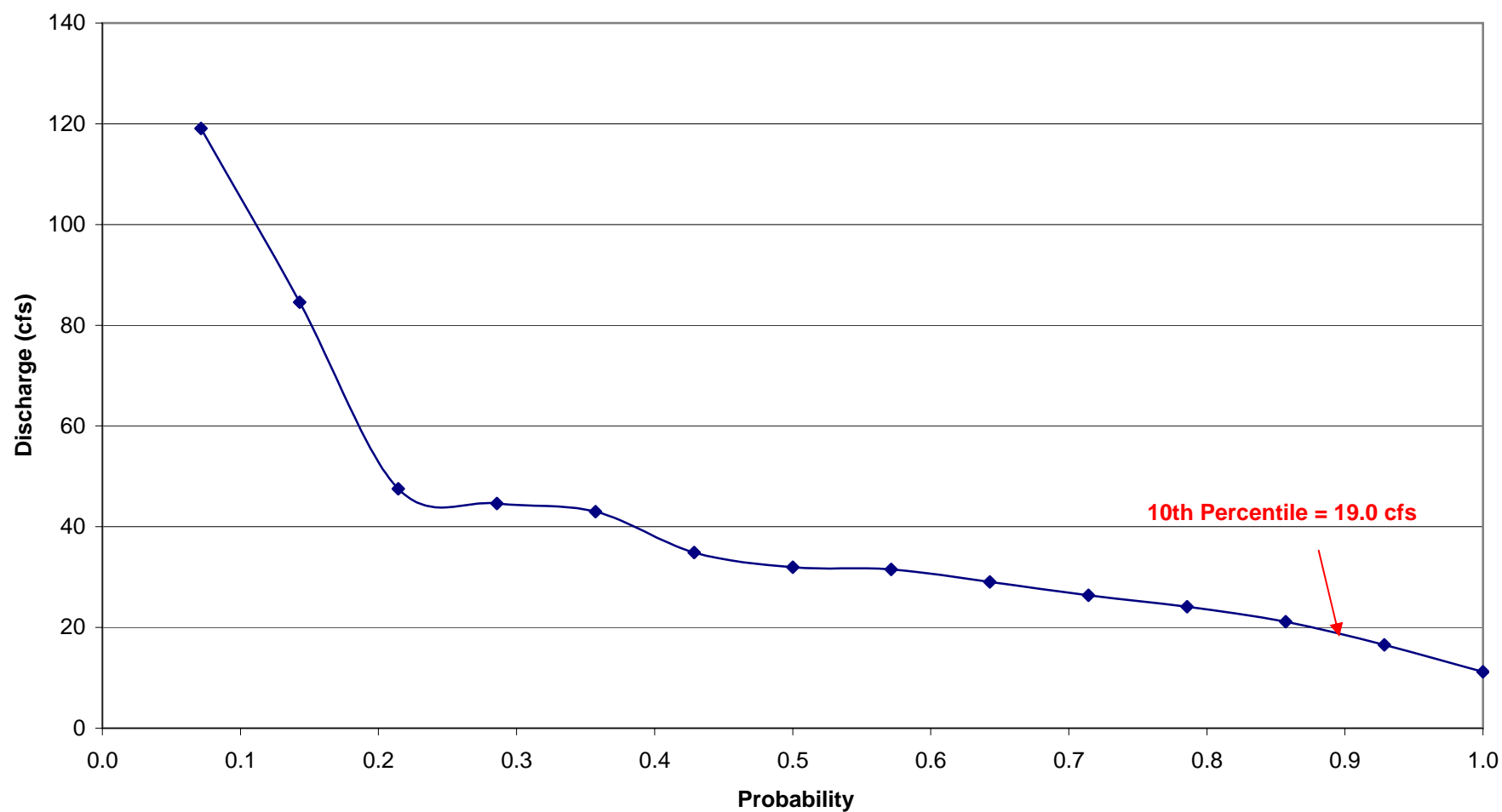


Figure 3 - Appendix F
Low Flow Analysis
Probability vs Flow Discharge for Harrison Bayou (Downstream)
Based on December 1999 to March 2000 Flow Derivation



Appendix G

*LHAAP-46 Calculation of Maximum Concentrations and
Dilution Factors of Contaminants Discharged to Goose Prairie
Creek from Groundwater*

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Simulation Results	3-1
4.0	References	4-1

List of Tables

Table 1	Maximum Concentrations and Chemical Properties for COCs at LHAAP-46
Table 2	Summary of Perchlorate Concentrations at Goose Prairie Creek – Middle, LHAAP-46

List of Figures

Figure 1	Environmental Sites – Modeling Report
----------	---------------------------------------

1.0 Introduction

LHAAP-46 is located on the northwestern portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-46 was referred to as Plant 2 Area. The chemical of concern is perchlorate in groundwater at a maximum concentration of 30 µg/L that is higher than the Texas interim action level (IAL) of 4 µg/L.

The purpose of the following modeling was to calculate the maximum concentration and dilution factors for perchlorate at the point of entry (POE) of groundwater and Goose Prairie Creek, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factor with the IAL. Groundwater flows to the east based on December 1998 water level measurements (Jacobs, 2002a). The distance from LHAAP-46 to Goose Prairie Creek-Middle is approximately 3,125 feet (**Figure 1**).

In order to calculate the maximum concentrations of perchlorate and the time of travel at the POE into Goose Prairie Creek, the computer code AT123D was used.

2.0 *Input Parameters and Assumptions*

Groundwater modeling at LHAAP-46 was based on the following assumptions and considerations:

- Contaminant Source: instantaneous source was assumed. Conservatively, the maximum concentration of perchlorate was assumed to cover the entire plume area. The maximum concentration of perchlorate was detected in monitoring well 46WW04 at a concentration of 30 µg/L. The only source is the current plume itself.
- The source area was assumed to be the plume area. The dimension of the plume was assumed to be 474 feet (east-west) by 274 feet (north-south) by 3 feet in depth for all the contaminants.
- Based on the geologic cross sections at LHAAP-46 (Figure 8-2 in Jacobs 2002a), the thickness of the shallow water bearing zone consisting of sand is 3 feet. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 3 feet.
- The properties of the shallow water bearing zone used in the model were as follows:
 - Hydraulic conductivity: 7.82×10^{-4} cm/sec (average value based on slug test data, [Jacobs, 2002a])
 - Hydraulic gradient: 0.009 (based on Figure 2-11 in Jacobs, 2001a)
 - Effective porosity assumed at 0.25
 - Longitudinal groundwater dispersivity: $= x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) where x is the travel distance of contaminants, assumed to be the distance from the source to Goose Prairie Creek = 312.5 feet
 - Transverse groundwater dispersivity: $= \alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995) = 104.2 feet
 - Vertical groundwater dispersivity: $= \alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995) = 15.6 feet

Chemical properties of perchlorate are listed in **Table 1**, basically K_d and degradation rate are neglected.

3.0 *Simulation Results*

Simulation shows that perchlorate will not exceed its IAL of 4 µg/l at the POE of groundwater into Goose Prairie Creek-Middle. Perchlorate will start to appear at the POE after 207 years with a concentration of only 0.01 µg/L and will not increase to its IAL of 4 µg/L because after 300 years, the maximum concentration at Goose Prairie Creek-Middle is only 0.07 µg/L (**Table 2**). Even in the entire flow system, the peak concentration is only 4.12 µg/L after 200 years, occurring at 833 feet downgradient of the source.

Field Confirmation

The source plume of TCE at this site was assumed conservatively to cover an area of 474 ft x 274 ft in which the maximum concentration of perchlorate was detected at 30 µg/L at well 46WW04. There are several wells downstream of this well. However, these wells are in the plume area or along the center line of the flow path. For this reason, no evaluation of contaminant concentration at a lateral location downgradient was attempted to provide field confirmation of the model.

4.0 *References*

References are provided in the main document, Section 8.0.

Table 1
Maximum Concentrations and Chemical Properties for COCs at LHAAP-46

Chemical	Maximum Observed Concentration	MCL (µg/L)	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-Life years ⁽²⁾	Degradation Rate (1/year)
Perchlorate ⁽³⁾	30 µg/L (in groundwater)	4.0 ⁽⁴⁾	N/A	---	---	---	N/A	N/A

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard, et al., 1991, "Environmental Degradation Rates," assumed no degradation

(3) No data available, assumed no degradation and no water-soil partitioning

(4) action level

µg/L micrograms per liter

cm³/g cubic centimeters per gram

foc fraction organic carbon

Kd water-soil partition coefficient

Koc carbon-water sorption coefficient

MCL maximum contaminant level

m³/kg cubic meters per kilogram

N/A not available

Table 2
Summary of Perchlorate Concentrations
at Goose Prairie Creek - Middle
LHAAP-46, Longhorn Army Ammunition Plant

Source Type	Action Level	Source Area (north-south x east-west)	Maximum Observed Source Concentration	Distance to Goose Prairie Creek-Middle	Source Release Rate*	Years Contaminant Starts to Appear at Creek in groundwater (years)	Maximum Concentration in Groundwater at POE at Goose Prairie Creek- Middle (µg/L) (DF)	MSC Based on DF at Groundwater & Goose Prairie- Middle (µg/L)	Mixing Concentration in Creek (µg/L)	Overall MSC after Discharge into GPC-Middle (µg/L)
	(µg/L)	(feet x feet)	(µg/L)	(feet)	(kg)					
Perchlorate	4.0	274 x 474	30.0	3,125	0.126	207	0.07(300) (429)	1,716	NA	NA

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 11 feet.

* Instantaneous source release in kg = maximum source concentration x plume pore volume

µg/L micrograms per liter

DF dilution/attenuation factor

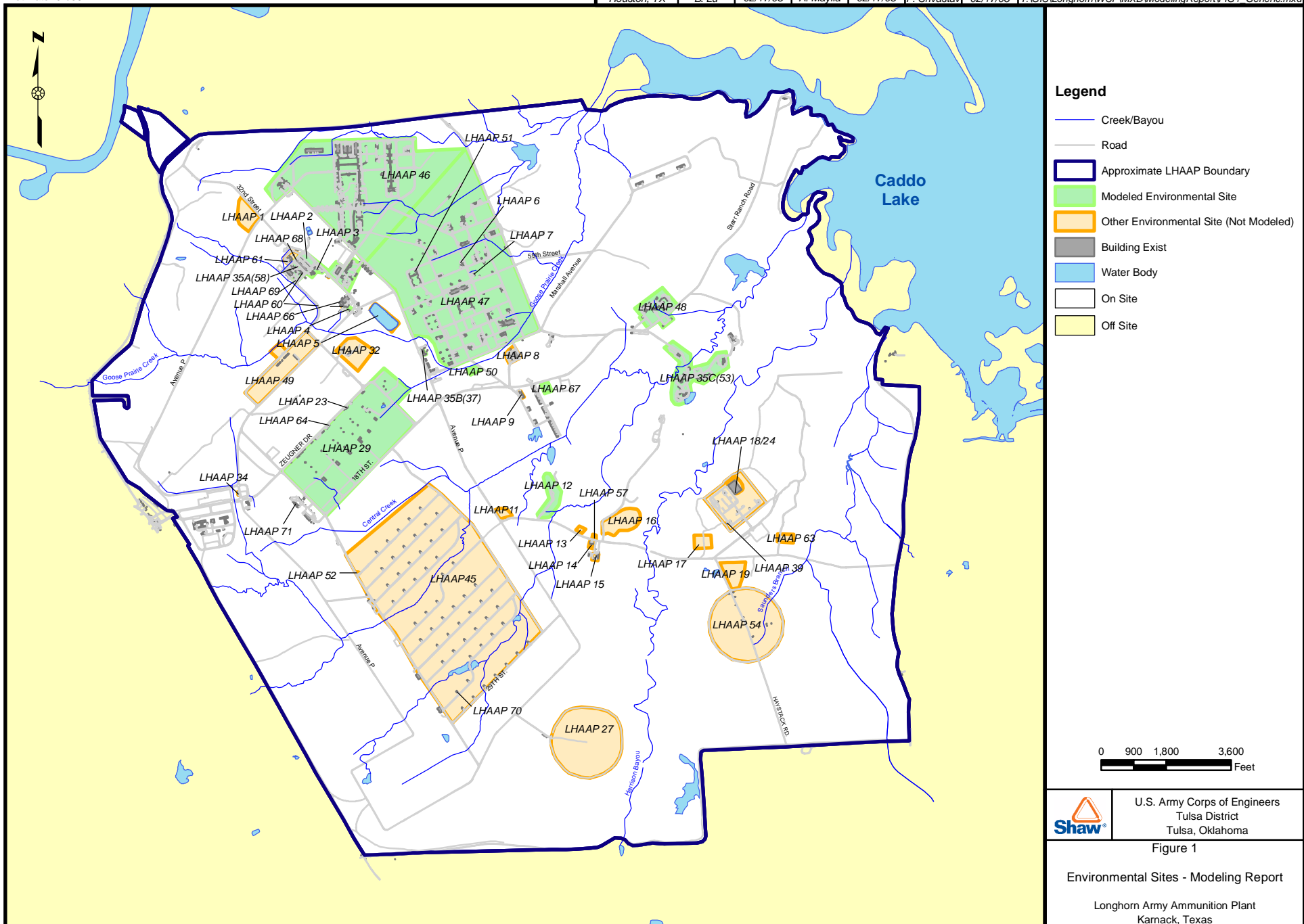
kg kilograms

MSC medium specific concentration

NA not analyzed or not applicable

POE point of entry

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\WMD\Modeling\Report\FIG1_Generic.mxd



Appendix H

LHAAP-47 Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Soil and Groundwater

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Simulation and Results	3-1
4.0	Soil Concentration of Perchlorate Protective of Sediment and Surface Water.....	4-1
4.1	Perchlorate Concentration in Erodable Soil Protective of Sediment	4-1
4.1.1	Soil Loss Calculation	4-1
4.1.2	Calculate ^{Sed} Soil MSC	4-3
4.2	Perchlorate Concentration in Erodable Soil Protective of Surface Water	4-4
5.0	Results	5-1
6.0	References	6-1

List of Tables

Table 1	Maximum Concentrations and Chemical Properties for COCs at LHAAP-47
Table 2	Summary of TCE, PCE, VC, PCP, and Perchlorate Concentrations at Goose Prairie Creek, LHAAP-47
Table 3	Rainfall/Runoff Erosivity (R Factor), Shreveport, Louisiana
Table 4	RUSLE Calculation Result for LHAAP-47 – Affected Area
Table 5	RUSLE Calculation Result for LHAAP-47 – Total Area
Table 6	Calculation of Flow Discharge in Goose Prairie Creek

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Trichloroethene Concentrations in Groundwater at Goose Prairie Creek (1,296 feet from Source), LHAAP-47
Figure 3	Vinyl Chloride Concentrations in Groundwater at Goose Prairie Creek (264 feet from Source), LHAAP-47
Figure 4	Perchlorate Concentrations in Groundwater at Goose Prairie Creek (312 feet from Source), LHAAP-47
Figure 5	Perchlorate Concentrations in Groundwater Contributed by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek (312 feet from Source), LHAAP-47
Figure 6	Low Flow Analysis – Probability vs Flow Discharge for Goose Prairie Creek

1.0 Introduction

LHAAP-47 is located in the north-central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-47 was referred to as Plant 3 Area. The chemicals of concern are trichloroethene (TCE), PCE, pentachlorophenol (PCP), vinyl chloride (VC), and perchlorate in groundwater and perchlorate in top soil. Perchlorate was detected in subsurface soil at a maximum concentration of 190,000 µg/kg at sampling location 25C-06 at a depth interval of 4 to 5 feet below ground surface. TCE, PCE, PCP, VC and perchlorate were detected in groundwater at maximum concentrations of 20,410, 168, 7.9, 127, and 82,900 µg/L, respectively (Jacobs, 2002a).

The purpose of the modeling was to calculate the maximum concentrations and dilution factors for COCs at the point of entry (POE) of groundwater into Goose Prairie Creek, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the MCLs or interim action level (IAL) for perchlorate. Calculations were also performed to develop subsurface perchlorate soil concentrations protective of sediment and surface water due to the erosion of soil by storm-generated runoff to the nearby surface water body.

Calculation of perchlorate leachate to groundwater was done using VLEACHSM. In order to calculate the maximum concentrations of the COCs and the time of travel at the POE at Goose Prairie Creek, the computer code AT123D was used.

2.0 Input Parameters and Assumptions

Soil leachate modeling and groundwater modeling at LHAAP-47 was based on the following assumptions and considerations:

- Contaminant Source.** No continuous source in the upper soil layer for TCE, PCE, PCP, and VC instantaneous source is assumed for these chemicals. For perchlorate, a maximum concentration of 190,000 µg/kg was detected in soil at a depth of 4 to 5 feet below ground surface. A continuous source is assumed for perchlorate for 10 years. At sampling location 25C-06, perchlorate leachate from soil is evaluated; at a depth of 0 to 0.5 feet: 7,000 µg/kg; 4 to 5 feet: 190,000 µg/kg; and 9 to 10 feet: 140,000 µg/kg. The concentration in the leachate was estimated with the model, VLEACHSM. Then, after mixing with groundwater, perchlorate transport was modeled to obtain concentrations at the point of entry (POE) at Goose Prairie Creek.
- The depth to groundwater is approximately 13 feet (Jacobs, 2000a)
- The dimension of the plume is assumed to be 200 feet (east-west) by 200 feet (north-south) by 6 feet in thickness for the other contaminants.
- The perchlorate plume transported to Goose Prairie Creek is assumed to be 50 feet wide.
- Based on the geologic cross sections at LHAAP-47 (Figures 9-2 through 9-6 – Jacobs, 2002a), the average thickness of the shallow water bearing zone is 6 feet. It is assumed that the contaminant source in this shallow zone extended to the entire thickness of 6 feet.
- Based on the locations of the COC plumes and the flow direction to Goose Prairie Creek, the distance of TCE, PCE, and PCP transport in groundwater to Goose Prairie Creek is 1,296 feet, the distance of VC transport in groundwater to Goose Prairie Creek is 264 feet, and the distance of perchlorate transport in groundwater to Goose Prairie Creek is 312 feet (Jacobs, 2002a).
- Chemical properties of perchlorate in soil: since perchlorate is kinetically nonlabile and sorption or natural reduction in the environment is not significant, the water-soil partition coefficient (kd) and degradation rate were assumed to be zero. The Henry's law constant and diffusivity in air were also assumed to be zero. The solubility of perchlorate was assumed to be 200,000 mg/L. This value corresponds to ammonium perchlorate, which has the highest solubility among other perchlorates.
- Dispersivities in Soil.** The longitudinal dispersivity was calculated based on the following equation (Dynamac Corporation, 1995):

$$\alpha_L = 1.072 \times 10^{-1} L_u^{0.584} \quad (L_u = 10 \text{ feet, source to water table})$$

$$= 0.41 \text{ ft}$$

Equation H1

$$\text{and the vertical dispersivity } \alpha_v = 0.3 \quad \alpha_L = 0.123 \text{ ft}$$

Equation H2

- Darcy's velocity.** Darcy's velocity (Dv) is required by VLEACHSM.

$$Dv = ki \text{ (k = hydraulic conductivity and i = hydraulic gradient)} \quad \textbf{Equation H3}$$

- Recharge Rate in soil was assumed to be a value of 1 inch per year.
- The properties of the shallow water bearing zone used in the model were as follows:
 - The average hydraulic conductivity (*K*) based on the slug tests at LHAAP-47 was estimated to be 7.49×10^{-4} cm/sec (Jacobs, 2002a)
 - Hydraulic gradient: 0.0071 feet/feet for TCE, PCE, PCP, and VC transport, and 0.00397 feet/feet for perchlorate transport because of different locations (Jacobs 2002a).
 - Longitudinal dispersivity: 129.6 feet for TCE, PCE, PCP; 26.4 feet for VC; 31.2 feet for perchlorate
 - Transverse dispersivity: 43.2 feet for TCE, PCE, PCP; 8.8 feet for VC; 10.4 feet for perchlorate
 - Vertical dispersivity: 6.48 feet for TCE, PCE, PCP; 1.31 feet for VC; 1.57 feet for perchlorate

Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 1**.

3.0 *Simulation and Results*

Computer simulation results were evaluated at the POE as shown in **Table 2**. The results include the time when COCs reach the POE, the time they reach their peaks, the maximum concentrations at this location, the dilution factors (DFs) and the MSC based on DF, and the action level.

Modeling results show that maximum concentrations of TCE (though elevated at the source), PCE, PCP, in groundwater at the POE at Goose Prairie Creek are less than their respective MCLs (**Table 2** and **Figure 2**). However, VC and perchlorate at concentrations of 46.1 and 66,820 µg/L, respectively, exceed the MCL or the action level (**Table 2** and **Figures 3** and **4**). After mixing in Goose Prairie Creek, VC and perchlorate concentrations are reduced to below the MCL or action level in the amount of 0.0039 µg/L and 3.13 µg/L, respectively (**Table 2**).

Note that perchlorate concentration at the POE comes from two sources: (1) current perchlorate plume with maximum concentration of 82,900 µg/L in groundwater, and (2) current perchlorate in soil with maximum concentration of 190,000 µg/kg. The predicted maximum concentration at the POE due to perchlorate already in the groundwater is 66,320 µg/L in 13.6 years. After 50 years, the maximum concentration drops to below 9,000 µg/L. At 13.6 years, the concentration of perchlorate at the POE in groundwater originating from soil leachate (using VLEACHSM) is approximately 500 µg/L (**Figure 5**). Therefore, the combined maximum concentration at the POE in groundwater is 66,820 µg/L. This value is the overall maximum concentration that would appear at the POE in groundwater. Even though the perchlorate concentration in groundwater at the POE generated by leachate would rise to 9,110 µg/L after 52 years, the combination of both concentrations from leachate and from the groundwater plume would not exceed 18,000 µg/L.

Field Confirmation

Additional calculations were conducted to simulate perchlorate concentrations at a well located in a transverse direction from the centerline of the flow. These calculations were conducted to compare the model results with actual field observations.

An evaluation of perchlorate concentration at a downgradient monitoring well, 50WW01, was made. This well is approximately 192 feet downgradient from the source but offsets the center flow line by 348 feet laterally to the southwest. The simulated concentration observed at this location is non-detect until after 30 years and peaks at 35.6 µg/L after 36 years of simulation. Currently perchlorate at this location is non-detect.

4.0 *Soil Concentration of Perchlorate Protective of Sediment and Surface Water*

Maximum perchlorate concentration in soil was detected at 190,000 µg/kg at sampling location 25C-06 at a depth interval of 4 to 5 feet. It is very unlikely that this layer of soil will be eroded considering the depth at which it exists. Therefore, the maximum concentration of 180,000 µg/kg detected at a depth of 1.5 to 2 feet below ground surface at 25C-21 was used to evaluate the transport of perchlorate by eroded soil.

Perchlorate in the subsurface soil (with a concentration of 180,000 µg/kg), together with the contaminated soil particles will be transported by storm-generated runoff to a nearby surface water body, Goose Prairie Creek. The shortest distance from the source to Goose Prairie Creek is approximately 192 feet. The approach to develop surface soil concentrations protective of sediment and surface water is described in the Technical Memorandum (Shaw Environmental, Inc, 2004a) and the following sections.

4.1 *Perchlorate Concentration in Erovable Soil Protective of Sediment*

A screening calculation was performed to evaluate whether storm water from an affected property has the potential to pose a risk to human or ecological receptors in the Goose Prairie Creek. First, soil loss from the effected property was evaluated by the revised universal soil loss equation (RUSLE) before soil concentration protective of sediment could be calculated.

4.1.1 *Soil Loss Calculation*

The RUSLE is in the form:

$$A = R \times K \times L \times S \times C \times P \quad \text{Equation H4}$$

where :

- A = Estimated average annual soil loss (ton/ac-yr)
- R = Rainfall-runoff erosivity factor (ft-ton-in/ac-hr-yr)
- K = Soil erodibility (ton/ac per unit of R)
- L = Slope length factor (unitless)
- S = Slope steepness factor (unitless)
- C = Cover management factor (unitless)
- P = Support practice factor (unitless)

The input parameters all depend on the location of the site being evaluated. The location factor actually implicitly describes rainfall, land use, surface coverage, soil type, and other factors in that location. Since LHAAP is close to Shreveport, Louisiana, some of the parameters established for Shreveport were used for LHAAP as described below.

- **Rainfall-runoff erosivity factor (*R*).** When the factors other than rainfall are held constant, soil losses from cultivated land are directly proportional to a rainstorm parameter: total storm energy (*E*) multiplied by the maximum thirty-minute intensity (*I*). *R* was obtained by using RUSLE software. The topographic slope in the affected area as well as the slope from LHAAP-47 to Goose Prairie Creek (total area) was estimated to be 2.22 percent. The overall *R* value of 400 was thus given in the template provided by RUSLE program. **Table 3** shows the annual precipitation of 43.8 inches with monthly distributions of rainfall and temperature for the city of Shreveport. Hourly *EI* distribution is also presented. The *R* factor was estimated and also presented in this template.
- **Soil erodibility (*K*).** The *K* factor is the ease with which soil is detached by splash during rainfall or by surface flow or by a combination of both. It is a function of the composition of soil type, percentage of organic matter, soil structure and grain size, and soil permeability. In this current evaluation, it was assumed that the topsoil consists of 39 percent silt and very fine sand, 60 percent clay, 1 percent organic matter, medium to coarse granular (less than 5 mm), and low permeability. The result of *K* factor, using these soil properties in a nomograph, is 0.12 for the affected area and the total area as shown in **Tables 4** and **5**, which is the soil loss and sediment yield computation worksheet.
- **Topographic factor, including *L* and *S* (*LS*).** The value of *LS* increases as hill slope length and steepness increase. In this calculation, only one single segment of slope was assumed. Soil texture and land use were assumed as silty clay and “disturbed topsoil, rock cover.” “Rock cover” was assumed to represent pavement and construction with impervious cover. The calculated *LS* values are 0.37 and 0.43 for the affected area and the total area, respectively, as shown in **Tables 4** and **5**.
- **Cover management factor (*C*).** The *C* factor is the ratio of soil loss with specific cropping and management practices to the corresponding loss with up-slope and down-slope tillage and continuously fallow conditions. The calculated values of *C* are 0.14 (affected area) and 0.18 (total area) as shown in **Tables 4** and **5**.
- **Support practice factor (*P*).** The *P* factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing on soil loss at a particular site. The *P* factor was calculated through the RUSLE equations and the results are 0.58 for both the affected area and the total area as shown in **Tables 4** and **5**.

The resultant soil losses calculated using the RUSLE program are 1.4 tons/ac-yr for the affected area and 2.2 tons/ac-yr for the total area.

In moving towards the outlet, soil will be trapped by vegetation and plant residue or deposited in low lying areas, local scour, rills and channels. Other factors that inhibit the eroded material’s delivery to the watershed outlet include climate, soil particle size and texture, size and proximity of the upland erosion source, the ratio of rill versus sheet erosion, total watershed area, watershed

length and relief, and drainage density. Therefore, not all of the soil loss calculated by the above approach will reach the watershed outlet. The sediment yield or load at the outlet should be estimated by using a sediment delivery ratio (SDR) from 0 to 1 to account for the deduction factors. RUSLE is designed in calculating the SDR by assigning different values for permanent barriers (strips or concaves) and terraces or sediment basins that include the land slope, soil type and texture, etc. Because many site-specific data are not available, assumptions are made. The SDR values estimated using RUSLE are 0.3 (affected area and total area) as shown in **Tables 4** and **5**.

The annual sediment yields calculated using RUSLE are 0.73 tons/ac-yr for the affected area and 1.1 tons/ac-yr for the total area (**Tables 4** and **5**).

4.1.2 Calculate ^{Sed}Soil MSC

The soil concentration protective of sediment, ^{Sed}Soil MSC (or C_{AP}), is calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT}) - (SL_{OA} \times C_{OA})}{SL_{AP}} \quad \text{Equation H5}$$

where:

- C_{AP} = the ^{Sed}Soil PCL (mg/kg) for the surface water runoff pathway from the affected area.
- SL_{TOT} = total sediment load estimated for the entire contributing watershed (1.1 tons/ac-yr = 1100 kg/ac-yr) (see **Section 4.1.1**).
- C_{TOT} = published regulatory standard for COC
- SL_{OA} = sediment load (kg/yr) estimated for other areas of the watershed.
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds. Because there is no Texas-specific median background soil concentrations, $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area.
- SL_{AP} = sediment load (kg/yr) from the affected property. In this case, 0.73 tons/ac-yr = 730 kg/ac-yr.

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT})}{SL_{AP}} \quad \text{Equation H6}$$

where:

- SL_{TOT} = 1100 kg/ac-yr
- SL_{AP} = 730 kg/ac-yr
- C_{TOT} = 25 mg/kg (sediment PCL for perchlorate for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002)

Therefore, $C_{AP}(\text{SedSoil MSC}) = (1100)(25)/730 = 37.7 \text{ mg/kg}$.

Note that the perchlorate concentration in soil at the source that can be eroded is 180 mg/kg, which is greater than the SedSoil MSC (37.7 mg/kg).

4.2 Perchlorate Concentration in Erodable Soil Protective of Surface Water

Screening for the pathway for the contaminant in erodable soil to surface water was conducted using conservative screening equations that account for some affected property and watershed characteristics. In this study, it is assumed conservatively that 7Q2 conditions in Goose Prairie Creek (flow in 7 consecutive days occurs once every 2 years) prevail and, therefore, pose a greater effect on the creek after mixing and dilution. Because the derived flow data in Goose Prairie Creek are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2.

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation H7}$$

where:

- C_{AP} = concentration of perchlorate in runoff from the affected property (mg/L)
- Q_D = flow downstream of the affected property watershed (ft³/sec), using 7Q2 flow
- C_D = concentration of perchlorate downstream of the affected property (mg/L)
- Q_{AP} = runoff from the affected property (ft³/sec)
- Q_{OA} = runoff from other areas of the affected property watershed (ft³/sec)
- C_{OA} = concentration of perchlorate in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U)$$

where:

- R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
- I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated (ft³/sec) using the following equation:

$$Q = P \times P_J \times R_{VU} \times A_U \quad \text{Equation H8}$$

where:

- P = precipitation rate (inches/year)
- P_J = ratio of storms producing runoff (unitless) with a default value of 0.9
- R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
- A_U = area of land use type U (acres)

At LHAAP-47, the affected property was estimated to be 0.0574 acres (50 feet × 50 feet). The annual precipitation at LHAAP was estimated to be 45 inches/year (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 50 percent and 10 percent, respectively. Therefore,

For the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.6)](0.0574)\} = 0.129 \text{ ft}^3/\text{sec}$$

Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and therefore the other areas of the affected property watershed are omitted.

$$Q_D = 2.5 \text{ ft}^3/\text{sec} \text{ (based on 7Q2 flow shown in Figure 6 and Table 6)}$$

The solute concentration of perchlorate in the solute, $Conc_{source}$ (mg/l), can be derived from the soil concentration of 180 mg/kg, $Conc_{soil}$ (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation H9}$$

where:

- ρ_b = bulk density of soil = assumed 1.7 g/cm³
- k_d = distribution coefficient = Assumed 0.0 cm³/g
- ϕ_w = water-filled porosity = 0.35
- ϕ_a = air-filled porosity = assumed 0.15
- H_c = Henry's law coefficient = assumed 0.0 (dimensionless)

$$Conc_{source} = \frac{180 \times 1.7}{(0.35 + 0.0 \times 0.15)} = 874,286 \text{ } \mu\text{g/L}$$

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.129)(874.29)/2.5 = 45.1 \text{ mg/L} = 45,100 \text{ } \mu\text{g/L}$$

This concentration ($C_D = 45,100 \mu\text{g/L}$) is much greater than the IAL of $4 \mu\text{g/L}$ for perchlorate in surface water.

When perchlorate concentration downstream of the affected property (C_D) is set equal to the IAL of $4 \mu\text{g/L}$, the resulting C_{AP} represents the risk-based perchlorate concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (2.5)(4)/(0.129) = 77.5 \mu\text{g/L}$$

Using the equation used above, perchlorate concentration in soil (C_{soil}) can be derived by:

$$C_{soil} = \frac{[\phi_w + H_c \phi_a] C_{AP}}{\rho_b} = [0.35 + 0.0(0.15)](77.5)/1.7 = 15.96 \mu\text{g/kg}$$

Thus, the observed perchlorate concentration of $180,000 \mu\text{g/kg}$ at the site is much greater than the value C_{soil} ($=^{\text{SW}}\text{Soil MSC}$) protective of the surface water.

5.0 Results

Simulation shows that TCE, PCE, PCP will not exceed their respective MCLs in groundwater at the POE at Goose Prairie Creek. VC and perchlorate, however, exceed their MCL or IAL at the POE. After mixing in Goose Prairie Creek, these two chemicals are diluted to less than their MCL or IAL. Estimation of perchlorate transport by eroded soil shows that the current perchlorate concentration in the upper soil (180,000 µg/kg) is not protective of sediment and surface water.

6.0 References

References are provided in the main document, Section 8.0.

Table 1
Maximum Concentrations and Chemical Properties for COCs at LHAAP-47

Chemical	Maximum Observed Concentration in GW (µg/L)	MCL (µg/L)	Koc(1) cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years(2)	Degradation Rate (1/year)
Trichloroethene	29,410.0	5.0	100.0	0.1	0.1	1.00E-04	4.5	0.154
Tetrachloroethene	168.0	5.0	155.0	0.1	0.155	1.55E-04	2	0.347
Vinyl Chloride	127.0	2.0	11.0	0.1	0.011	1.10E-05	3.4	0.204
Pentachlorophenol	7.9	1.0	1000.0	0.1	1	1.00E-03	4.2	0.165
Perchlorate ⁽³⁾	82,900.0	4.0 ⁽⁴⁾	N/A	---	---	---	N/A	N/A

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard et al., 1991, "Environmental Degradation Rates"

(3) No data available, assumed no degradation and no water-soil partitioning

(4) action level

µg/L micrograms per liter

% percent

cm³/g cubic centimeters per gram

foc fraction organic carbon

Kd water-soil partition coefficient

Koc carbon-water sorption coefficient

m³/kg cubic meters per kilogram

Table 2
Summary of TCE, PCE, VC, PCP, and Perchlorate Concentrations
at Goose Prairie Creek
LHAAP-47

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Goose Prairie (feet)	Source Release Rate* (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration at POE at Goose Prairie (µg/L) (DF)	MSC Based on DF at POE at Goose Prairie (µg/L)	Mixing Concentration in Goose Prairie Creek (µg/L)	Overall MSC after Discharge into Goose Prairie Creek (µg/L)
Trichloroethene	5.0	200 x 200	29,400.0	1,296	70.000	12	1.08 (30.5 years) (27,222)	136,110	NE	NE
Tetrachloroethene	5.0	200 x 200	168	1,296	0.400	Infinity	0 (Infinity)	Infinity	NE	NE
Vinyl Chloride	2.0	200 x 200	127	264	0.302	0.25	46.1 (3.62 years) (2.75)	5.5	0.0039	65,128
Pentachlorophenol	1.0	200 x 200	7.9	1,296	0.019	Infinity	0 (Infinity)	Infinity	NE	NE
Perchlorate	4 ^(a)	200 x 200	82,900.0	312	197.450	0.5	66,820 (13.6 years) (1.24)	4.96	3.13	105,942

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 5 feet.

* Instantaneous source release rate in kg = maximum source concentration x porosity x source area x thickness of layer

^(a) Texas action level

µg/L micrograms per liter

DF dilution/attenuation factor

kg kilograms

MCL maximum contaminant level

mg/L milligrams per liter

MSC medium-specific concentration

NE not evaluated due to concentration in groundwater already below MCL, MSC or action level at POE

POE point of entry

Table 3
Rainfall/Runoff Erosivity (R Factor)
Shreveport, Louisiana

City code: 18003	City: Shreveport	State: LA	
Total P: 43.8 "	El curve #: 96	Freeze-Free days/year: 272	
Elevation (ft): 252	10 yr El: 180	R factor: 400	
Mean P (")	Tave (deg. F)	%El	%El
4.02	47.8	0	54
3.46	51.7	2	58
3.77	58.15	4	62
4.71	67.05	6	66
4.7	73.7	9	70
3.54	81.2	12	74
3.56	83.45	17	78
2.52	84.15	23	82
3.29	78.75	30	86
2.63	68.45	37	90
3.77	56.25	43	94
3.87	49.8	49	97

Table 4
RUSLE Calculation Result for LHAAP-47 – Affected Area

	R	K	LS	C	P	SDR	A	SY
SITE47AFF	400	0.12	0.37	0.14	0.579	0.30	1.4	0.73
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes and Abbreviations:

Annual sediment yield: 1.2 tons/ac-yr
A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Table 5
RUSLE Calculation Result for LHAAP-47 – Total Area

	R	K	LS	C	P	SDR	A	SY
SITE47ALL	400	0.12	0.43	0.1801	0.58	0.30	2.2	1.1
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

Notes and Abbreviations:

Annual sediment yield: 1.2 tons/ac-yr
A area
C cover management factor
K soil erodability
L slope length factor
P support practice factor
R rainfall – runoff erosivity factor
S slope steepness factor
SDR sediment delivery ratio
SY sediment yield

Table 6
Calculation of Flow Discharge in Goose Prairie Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (feet ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.10830	0.22081	1.44906	4.88410	2.80	4.20	4.0574	20.5132	12.2853
	10 - 16	0.11651	0.30483	0.48774	2.94988	3.21	6.87	1.5656	20.2657	10.916
	17 - 23	0.06315	0.37523	0.45438	2.12994	2.10	8.56	0.9542	18.2323	9.593
	24 - 30	0.06315	0.36534	0.45438	14.99560	2.10	7.88	0.9542	118.1653	59.560
Jan-00	1 - 7	0.02700	0.36224	0.21000	7.10767	1.05	7.98	0.2205	56.7192	28.470
	8 - 14	0.12681	0.44958	0.24389	11.82963	3.45	18.63	0.8414	220.3860	110.614
	15 - 21	0.03749	0.36559	0.03032	11.51831	1.41	8.35	0.0428	96.1779	48.110
	22 - 28	0.06279	0.42399	0.80813	14.08148	2.08	17.56	1.6809	247.2708	124.476
Feb-00	1 - 7	0.09417	0.42572	0.12182	9.59478	2.65	20.51	0.3228	196.7889	98.556
	8 - 14	0.05132	0.37422	0.04973	6.47123	1.75	8.01	0.0870	51.8346	25.961
	15 - 21	0.03763	0.37675	0.04530	0.53829	1.48	9.24	0.0670	4.9738	2.520
	22 - 28	0.14625	0.48311	0.35183	1.14280	4.45	20.51	1.5656	23.4388	12.502
Mar-00	1 - 7	0.10288	0.37274	0.16989	0.50621	2.79	7.95	0.4740	4.0244	2.249
	8 - 14	0.20995	0.58798	0.48053	1.13559	6.10	21.55	2.9312	24.4720	13.702

Notes and Abbreviations:

Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs cubic feet per second

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd

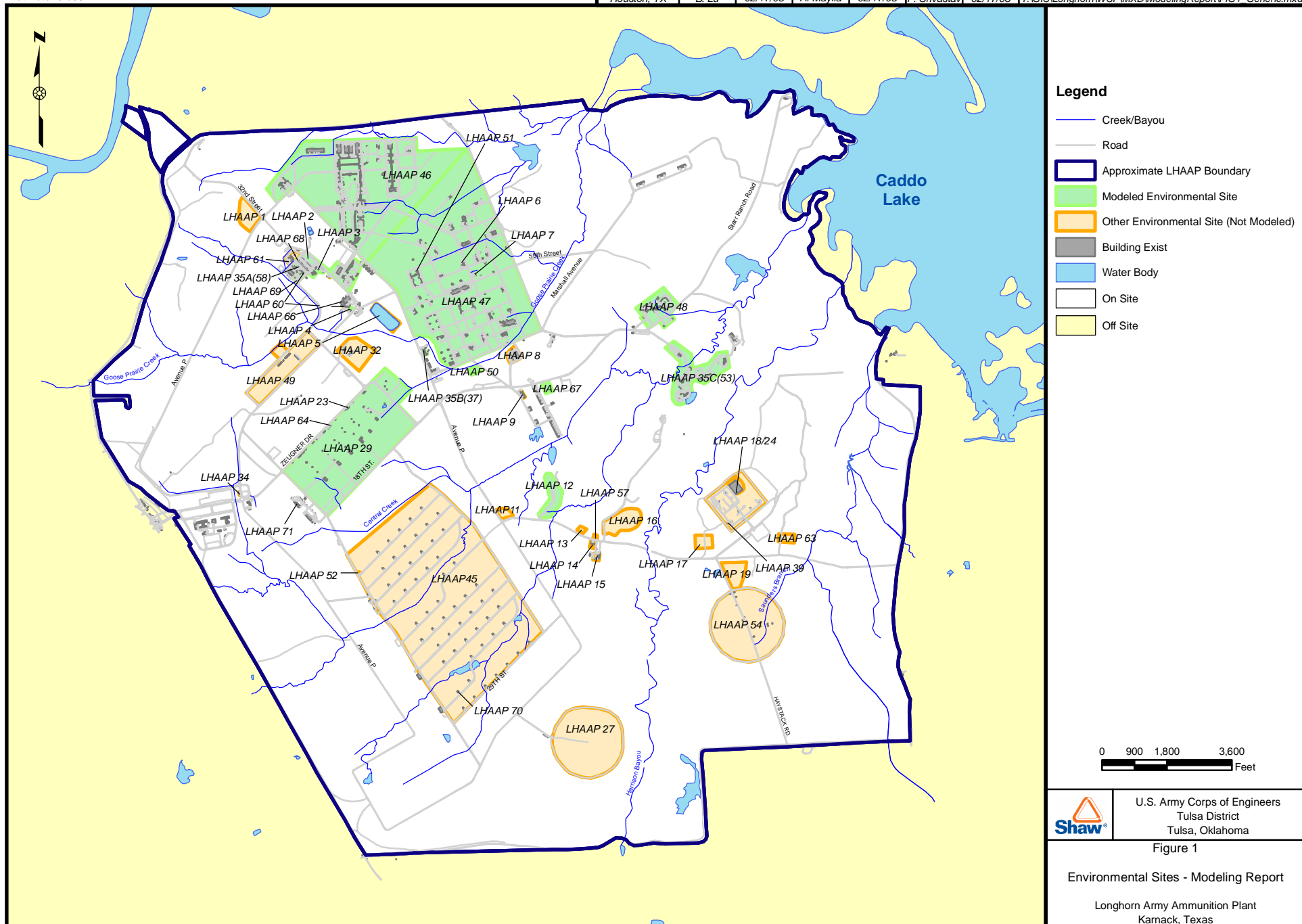


Figure 2 - Appendix H
Trichloroethene Concentrations in Groundwater at Goose Prairie Creek
(1296 feet from Source)
LHAAP-47, Longhorn Army Ammunition Plant, Texas

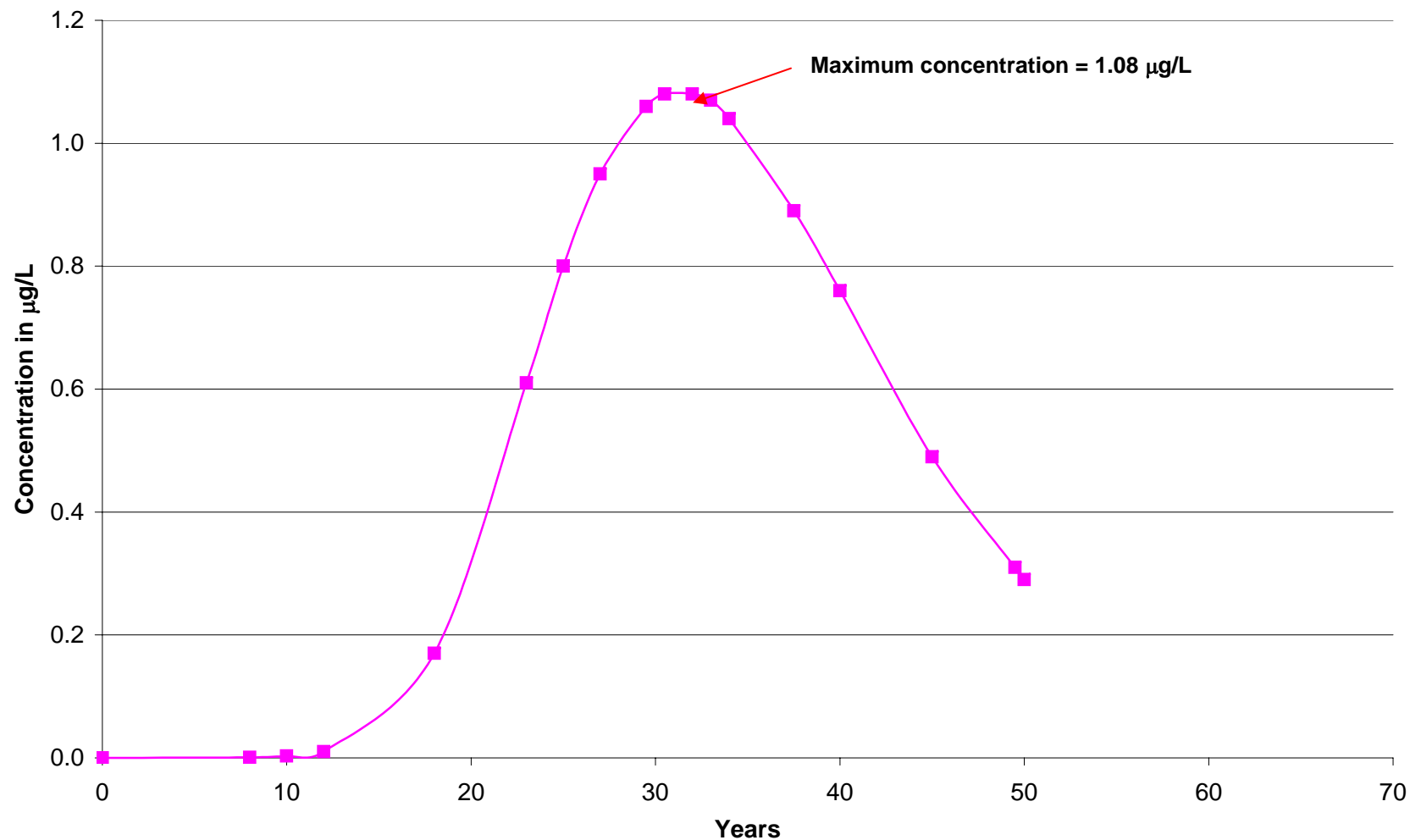


Figure 3 - Appendix H
Vinyl Chloride Concentrations in Groundwater at Goose Prairie Creek
(264 feet from Source)
LHAAP-47, Longhorn Army Ammunition Plant, Texas

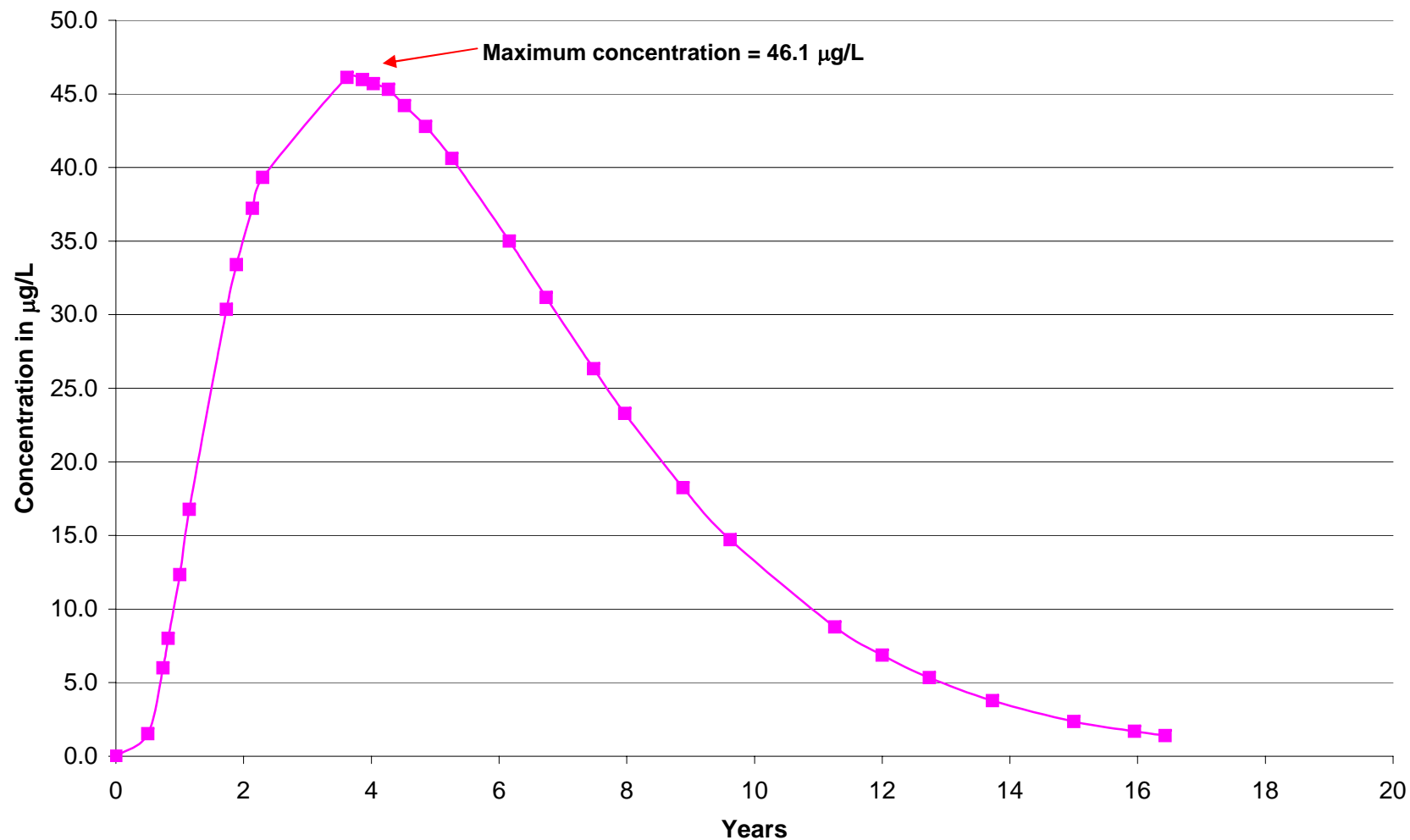


Figure 4 - Appendix H
Perchlorate Concentrations in Groundwater at Goose Prairie Creek
(312 feet from Source)
LHAAP-47, Longhorn Army Ammunition Plant, Texas

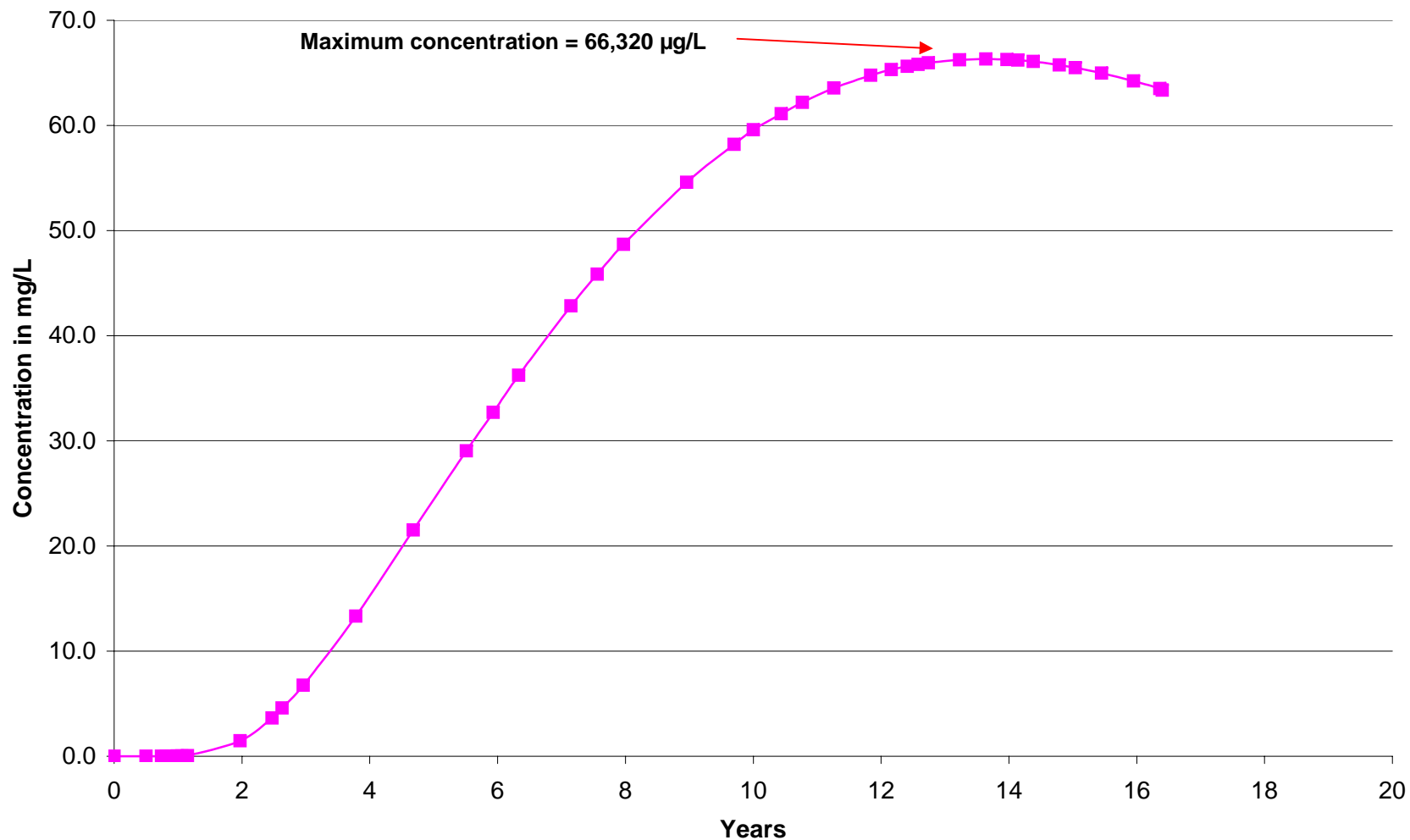


Figure 5 - Appendix H
Perchlorate Concentrations in Groundwater Contributed
by Soil Leachate at the Source Area and in Groundwater at Goose Prairie Creek
(312 feet from Source)
LHAAP-47, Longhorn Army Ammunition Plant, Texas

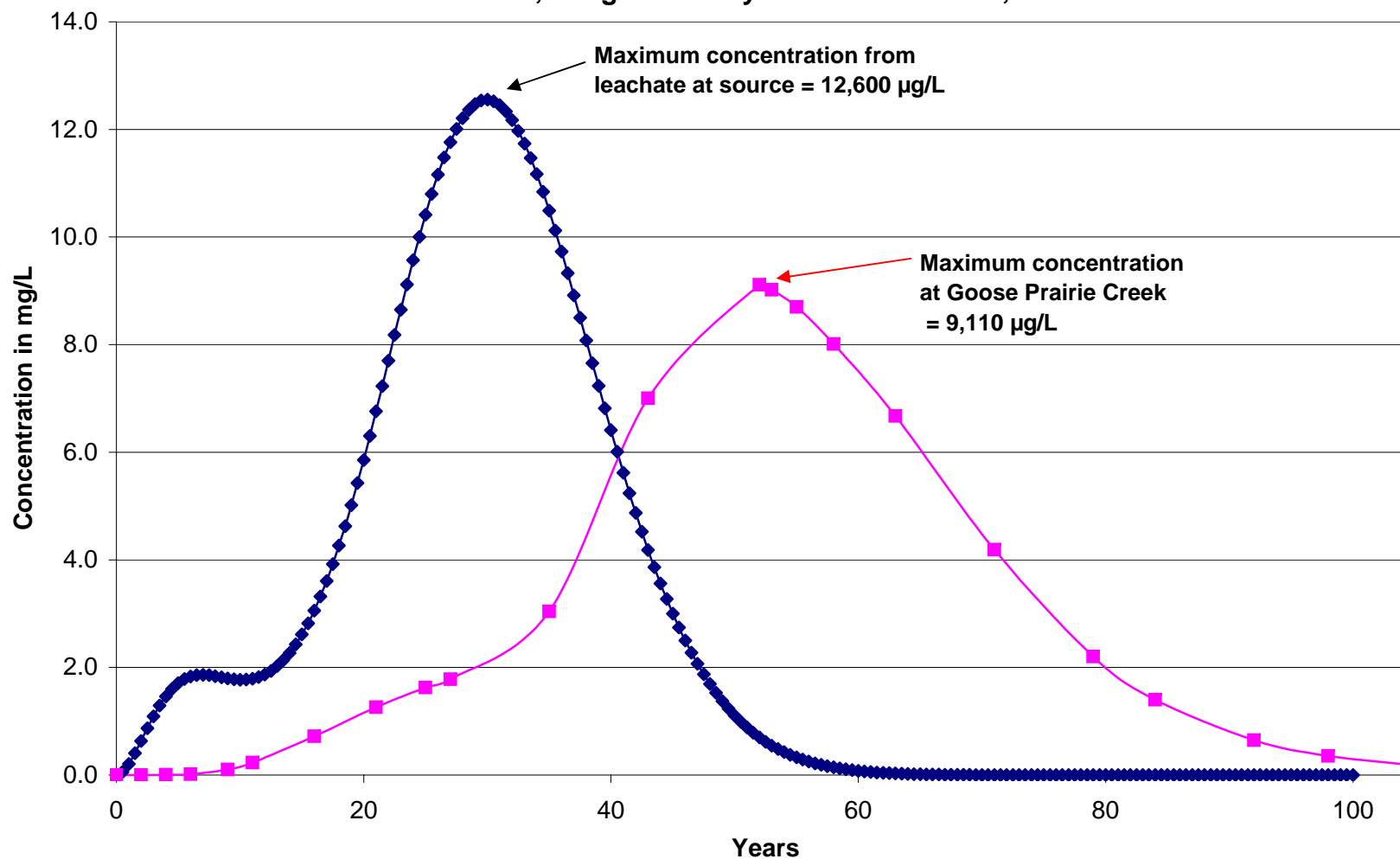
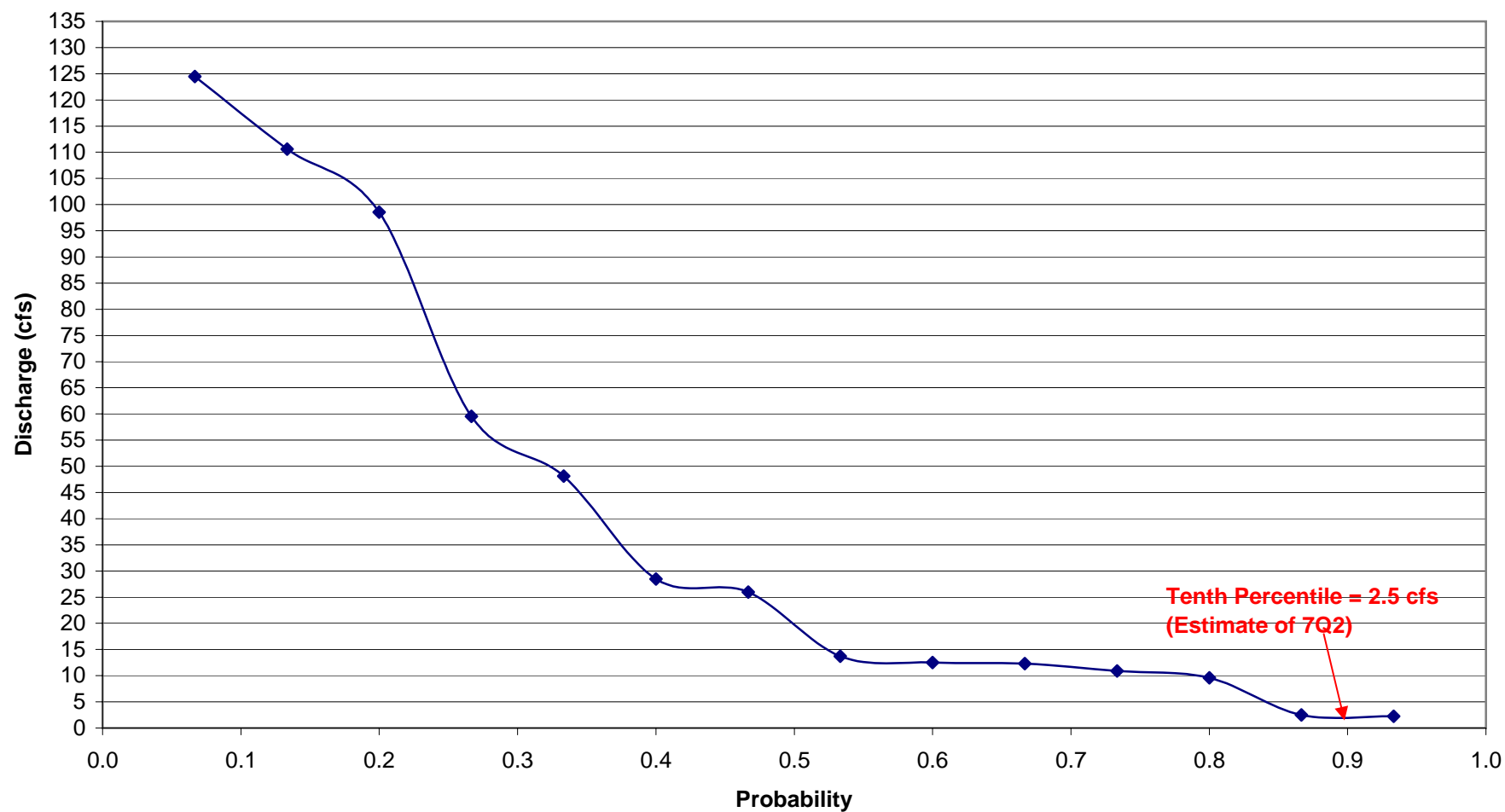


Figure 6 - Appendix H
Low Flow Analysis
Probability vs Flow Discharge for Goose Prairie Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix I

LHAAP-48 Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Central Creek from Groundwater

Table of Contents

1.0	Introduction	1-1
2.0	Assumptions and Conditions	2-1
3.0	Groundwater Protective of Surface Water	3-1
4.0	References	4-1

List of Tables

Table 1	Maximum Concentrations and Chemical Properties for COCs at LHAAP-48
Table 2	Calculation of Flow Discharge in Central Creek (Downstream)
Table 3	Summary of TCE and Perchlorate Concentrations at the Tributary of Central Creek, LHAAP-48

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Low Flow Analysis – Probability vs Flow Discharge for Central Creek (Downstream)

1.0 Introduction

LHAAP-48 is located in the east-central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-48 was also known as the Y-Area or Igniter Area. The chemicals of concern are trichloroethene (TCE) and perchlorate in groundwater at maximum concentrations of 9 and 160 µg/L, respectively. The chemicals of concern (COCs) are at levels that are higher than their respective maximum contaminant level (MCL) and action level.

The purpose of the modeling was to calculate the maximum concentrations and dilution factors for each COC at the point of entry (POE) of groundwater into the surface water, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the MCL for TCE, and interim action level (IAL) for perchlorate. The closest surface water body is Central Creek. Groundwater flows to the southeast based on December 1998 water level measurements (Jacobs, 2002a).

Because LHAAP-48 is located on both sides of the tributary of the Central Creek and the monitoring wells are very close to this tributary, it was assumed conservatively that the maximum concentration of TCE and perchlorate occurred at the creek. Therefore, no groundwater flow and transport modeling was performed.

Elevated vinyl chloride and tetrachloroethene were also found in the top soil at the site. The leaching modeling and the evaluation of soil concentration protective of sediment and surface water is addressed in Appendix L.

2.0 *Assumptions and Conditions*

In modeling LHAAP-48, several site specific conditions and assumptions were made. These include the origin of the contaminant source and assumptions made regarding properties of the shallow water bearing zone. These assumptions and conditions are detailed below.

- Contaminant source: No continuous source in the upper soil layer is assumed. It was assumed that TCE and perchlorate plumes are at the tributary of Central Creek. No groundwater modeling is required, only a mixing calculation was performed – a conservative approach. Observed maximum concentrations are assumed to be present in the groundwater at the POE into Central Creek.
- The properties of the shallow water bearing zone used in the calculation were as follows:
 - Average shallow water bearing zone thickness: 10 feet (no geologic cross sections were available, the well screen average length was used instead)
 - Average hydraulic conductivity (K) based on the slug tests at LHAAP-48 was estimated to be 3.8×10^{-5} cm/sec (Jacobs, 2002a)
 - Hydraulic gradient: 0.00679 feet/feet based on the groundwater level map (Figure 3B, Appendix A – September 2000 potentiometric surface map; Jacobs, 2001a)

Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 1**.

3.0 Groundwater Protective of Surface Water

Because LHAAP-48 is located on both sides of the tributary of Central Creek and the monitoring locations are very close to the tributary, it was assumed conservatively that the maximum concentrations of TCE and perchlorate observed at the site also occurred at the POE at the creek.

The mixing concentration of TCE and perchlorate in Central Creek was based on the flow discharge from the groundwater into the creek and the flow in the creek using 7Q2 estimation, which is the 10th percentile flow derived from the TCEQ approach (2003) (**Figure 1** and **Table 2**).

$$\begin{aligned}\text{Dilution factor in the creek (DF)} &= (Q_{\text{gw}} + 7Q2)/Q_{\text{gw}} = (3.46 \times 10^{-5} + 1.75)/3.46 \times 10^{-5} \\ &= 50,579\end{aligned}$$

Mixing concentration for TCE in Central Creek: $9/50579 = 1.8 \times 10^{-4} \mu\text{g/L}$

Mixing concentration for perchlorate: $160/50579 = 3.2 \times 10^{-3} \mu\text{g/L}$

Mixing calculation results show that concentrations of TCE ($1.8 \times 10^{-4} \mu\text{g/L}$) and perchlorate ($3.2 \times 10^{-3} \mu\text{g/L}$) in the tributary of Central Creek are much lower than their respective MCL and IAL (**Table 3**). These concentrations are, therefore, protective of surface water.

4.0 References

References are provided in the main document, Section 8.0.

Table 1
Maximum Concentrations and Chemical Properties for COCs at LHAAP-48

Chemical	Maximum Observed Concentration in GW (µg/L)	MCL (µg/L)	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
Trichloroethene	9	5.0	100.0	0.1	0.1	1.00E-04	4.5	0.154
Perchlorate ⁽³⁾	160	4.0 ⁽⁴⁾	N/A	---	---	---	N/A	N/A

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard, et al., 1991, "Environmental Degradation Rates"

(3) No data available, assumed no degradation and no water-soil partitioning

(4) Texas interim action level

% percent

µg/L micrograms per liter

cm³/g cubic centimeters per gram

COC contaminant of concern

foc fraction organic carbon

Kd water-soil partition coefficient

Koc carbon-water sorption coefficient

m³/kg cubic meters per kilogram

mg/kg milligrams per kilogram

N/A not available

NE not estimated

Table 2
Calculation of Flow Discharge in the Central Creek (Downstream)
(Data Collected from Dec 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth	Measured Velocity	Cross Sectional Area	Calculated Discharge
		(ft)	(ft/s)	(ft ²)	(cfs)
		Downstream	Downstream	Downstream	Downstream
Dec-99	3 - 9	1.11074	1.29100	6.31	8.1462
	10 - 16	1.48660	0.25542	7.30	1.8646
	17 - 23	1.46344	0.73705	7.25	5.3436
	24 - 30	1.32520	0.23729	7.00	1.6610
Jan-00	1 - 7	1.06090	0.29642	11.90	3.5274
	8 - 14	1.62076	0.19877	10.80	2.1467
	15 - 21	1.48365	0.15027	7.20	1.0819
	22 - 28	1.36087	3.31644	11.00	36.4808
Feb-00	1 - 7	1.63820	0.54047	6.12	3.3077
	8 - 14	1.51571	0.25153	11.70	2.9429
	15 - 21	1.44892	1.64454	7.26	11.9394
	22 - 28	1.55024	0.25240	7.15	1.8047
Mar-00	1 - 7	2.07625	3.62250	17.90	64.8428
	8 - 14	2.40898	2.59353	25.30	65.6163

Notes and Abbreviation:

Measured depths and measured velocities are averaged values over every seven days.

Cross sectional areas are based on the measured depths and cross sections .

cfs cubic feet per second

ft² square feet

Table 3
Summary of TCE and Perchlorate Concentrations
at the Tributary of Central Creek
LHAAP-48

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Tributary of Central Creek (feet)	Source Release Rate (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration in Groundwater at POE at the Tributary of Central Creek (µg/L)	MSC Based on DF at POE at the Trib. Of Central Creek (mg/L)	Mixing Concentration in Tributary of Central Creek (µg/L)	Overall MSC after Discharge into Tributary (µg/L)
Trichloroethene	5.0	NE	9.0	0	NE	NE	9	NE	1.80E-04	13,805,555
Perchlorate	4 ^(a)	NE	160.0	0	NE	NE	160	NE	3.20E-03	200,000

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 10 feet.

^(a) Texas interim action level

µg/L micrograms per liter

DF dilution factor

kg kilograms

MCL maximum contaminant level

mg/L milligrams per liter

MSC medium specific concentration

NE not evaluated due to allocation of maximum concentrations at point of exposure without any modeling

POE point of entry

TCE trichloroethene

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd

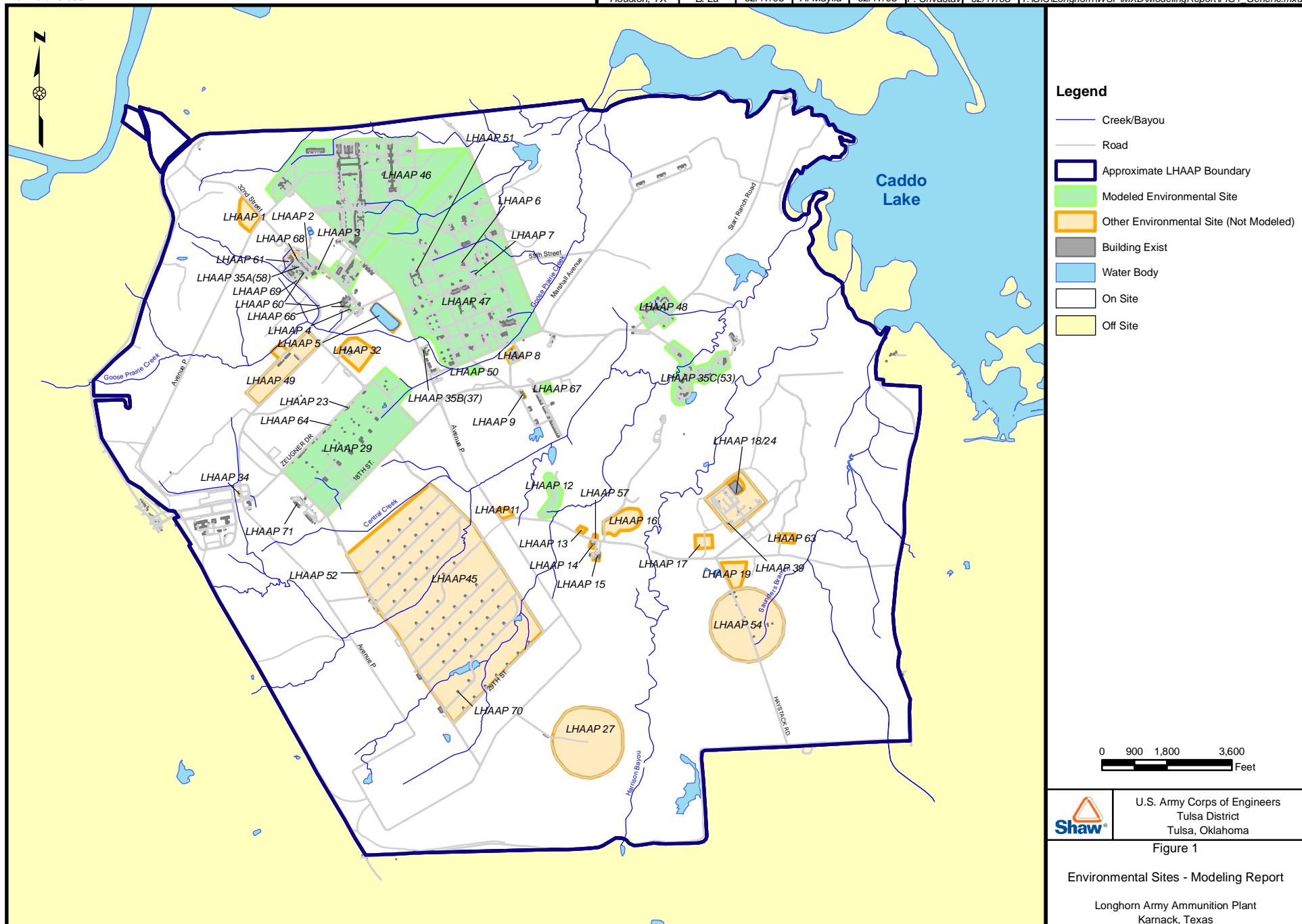
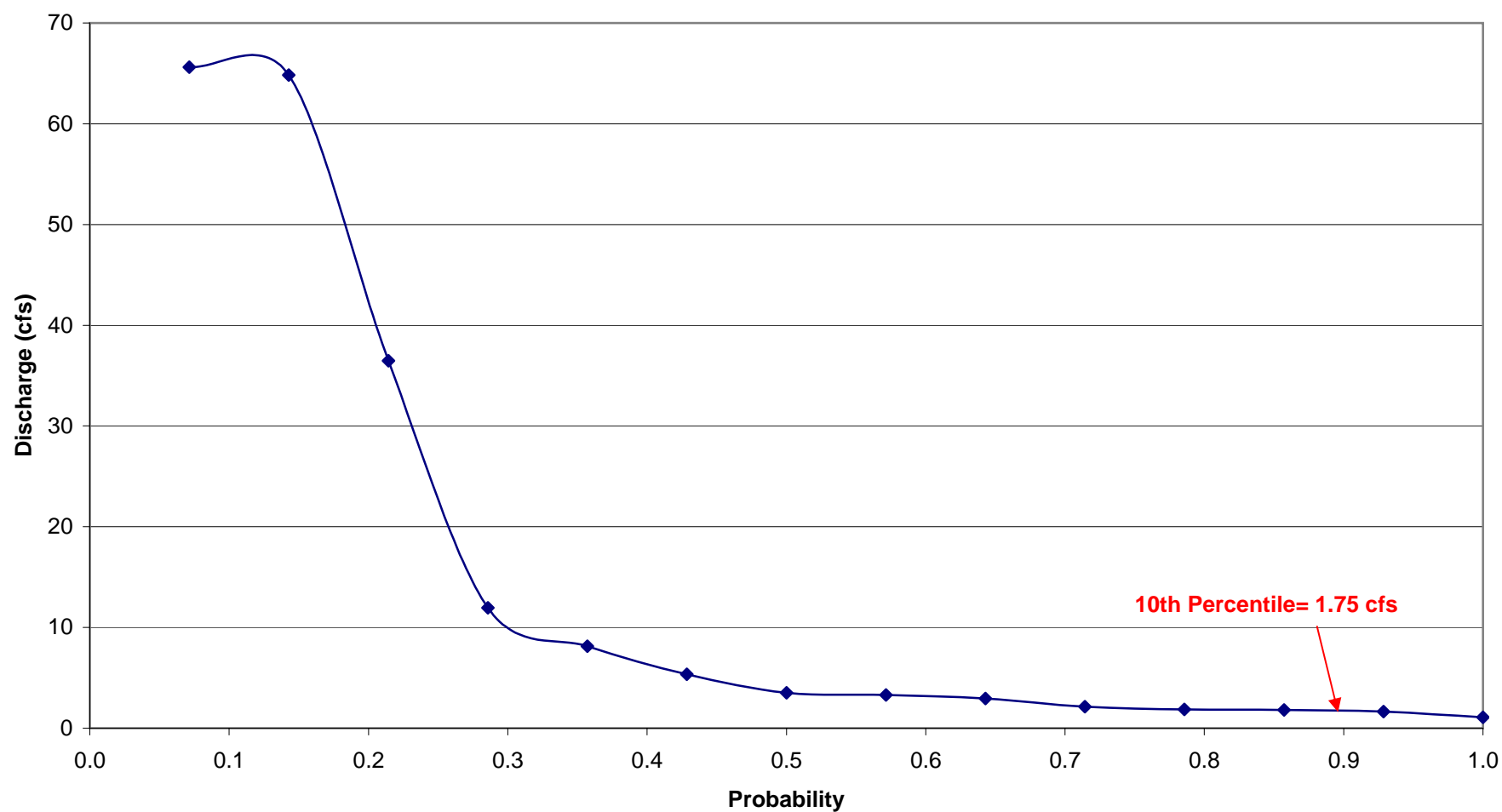


Figure 2 - Appendix I
Low Flow Analysis
Probability vs Flow Discharge for Central Creek (Downstream)
Based on December 1999 to March 2000 Flow Derivation



Appendix J

LHAAP-50 Calculation of Maximum Concentrations and Dilution Factors of Contaminants Discharged to Goose Prairie Creek from Groundwater

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Groundwater Protective of Surface Water	3-1
3.1	Dilution in Goose Prairie Creek	3-1
4.0	References	4-1

List of Tables

Table 1	Maximum Concentrations and Chemical Properties for COCs at LHAAP-50
Table 2	Summary of TCE, PCE, Vinyl Chloride, 1,2-Dichloroethane, and Perchlorate Concentrations at Goose Prairie Creek, LHAAP-50
Table 3	Calculation of Flow Discharge in Goose Prairie Creek

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Trichloroethene Concentrations in Groundwater at Goose Prairie Creek (132 feet from Source), LHAAP-50
Figure 3	Vinyl Chloride Concentrations in Groundwater at Goose Prairie Creek (132 feet from Source), LHAAP-50
Figure 4	Perchlorate Concentrations in Groundwater at Goose Prairie Creek (132 feet from Source), LHAAP-50
Figure 5	Low Flow Analysis – Probability vs Flow Discharge in Goose Prairie Creek

1.0 Introduction

LHAAP-50 is located on the north-central portion of Longhorn Army Ammunition Plant (**Figure 1**). LHAAP-50 was identified as an aboveground storage tank for industrial wastewater collected from industrial waste production sumps located at various sites throughout LHAAP. The chemicals of concern (COCs) are trichloroethylene (TCE), tetrachloroethene (PCE), vinyl chloride (VC), 1,2-dichloroethane (1,2-DCA) and perchlorate in groundwater at maximum concentrations of 22,000, 35, 100, 98 and 18, 000 $\mu\text{g/L}$, respectively (Jacobs, 2002a). The COCs are at levels that are higher than their respective maximum contaminant levels (MCLs) and action levels.

The purpose of the modeling was to calculate the maximum concentrations and dilution factors for each COC at the interface of groundwater and Goose Prairie Creek, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying the dilution factors with the applicable regulatory standards. The closest surface water body is Goose Prairie Creek. Groundwater flows to the northeast based on September 2000 water level measurements (Jacobs 2001a). The distance from LHAAP-50 to Goose Prairie Creek is approximately 132 feet.

In order to calculate the maximum concentrations of the COCs and the time of travel just before they are discharged to Goose Prairie Creek, the computer program AT123D was used.

2.0 *Input Parameters and Assumptions*

Groundwater modeling at LHAAP-50 was based on the following assumptions and considerations:

- Contaminant source: No continuous source in the upper soil layer for contaminants, instantaneous source is assumed for these chemicals.
- Conservatively, it was assumed that the plumes are approximately 132 feet from Goose Prairie Creek and the groundwater flow is to the northeast direction (parallel to the creek) as shown on the potentiometric surface map based on September 2000 water level measurements (Jacobs, 2001a).
- Average shallow water bearing zone thickness: 10 feet (no geologic cross section is available, well screen average length is used instead)
- The properties of the shallow water bearing zone used in the model were as follows:
 - The average hydraulic conductivity (K) based on the slug tests at LHAAP-47 was estimated to be 1.26×10^{-4} cm/sec (Jacobs, 2002a)
 - Hydraulic gradient: 0.0038 feet/feet based on the groundwater level map (September 2000 – Jacobs, 2001a)
 - Effective porosity assumed at 0.25
 - Longitudinal groundwater dispersivity: $= x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) where x is the travel distance of contaminants, assumed to be the distance from the source to the Goose Prairie Creek = 13.2 feet
 - Transverse groundwater dispersivity: $= \alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995) = 4.4 feet
 - Vertical groundwater dispersivity: $= \alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995) = 0.2 feet
 - Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, degradation rate, and half-life are listed in **Table 1**. Due to dechlorination as evidenced by the existence of TCE and VC, the daughter products of PCE, degradation rates at the site were assumed for these chemicals using literature values (Table 1, Howard et al., 1991).

3.0 Groundwater Protective of Surface Water

LHAAP-50 is located on the southern side of Goose Prairie Creek and the distance between the creek and plume is very short. However, groundwater flows parallel to the creek. Conservatively, it was assumed that the groundwater flows toward the creek in an event of change of groundwater flow direction. Computer modeling using AT123D shows that the maximum concentrations of TCE (567.5 µg/L), VC (5.32 µg/L), and perchlorate (17,800 µg/L) in groundwater at the point of entry into the creek are higher than their respective regulatory levels (**Table 2** and **Figures 2, 3, and 4**). Therefore, mixing concentrations in the creek for these three chemicals were calculated. Concentrations of PCE and 1,2-DCA are way below MCLs at the creek.

3.1 Dilution in Goose Prairie Creek

TCE, VC, and perchlorate in groundwater are subject to mixing and dilution after they are discharged into Goose Prairie Creek.

The DF of perchlorate after mixing with surface water in Goose Prairie Creek is calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW} + Q_{CC}}{Q_{GW}} \quad \text{Equation J1}$$

where Q_{CC} and Q_{GW} are the flow rates in Goose Prairie Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} * \delta_p * L_m \quad \text{Equation J2}$$

where U_{gw} , δ_p and L_m are the approaching groundwater seepage velocity, the thickness and width of the plume approaching surface water. U_{gw} ($= Ki/n$) is 1.98 feet/year, calculated based on the hydraulic conductivity of 1.26×10^{-4} cm/sec, hydraulic gradient of 0.0038 and the effective porosity of 0.25. δ_p is 10 feet and L_m is unknown at the intersection but can be conservatively assumed as the width at the source, which is 100 feet (northwest-southeast direction). Then:

$$Q_{GW} = 1.981 / (365 \times 86400) \times 10 \times 100 = 6.283 \times 10^{-5} \text{ ft}^3/\text{s} \quad \text{Equation J3}$$

Calculation of Q_{CC} must be based on the 7Q2 stream flow analysis. The 7Q2 is the low flow at the point of entry, defined as the flow discharge in seven consecutive days that occurs once every two years, statistically. At Goose Prairie Creek, two sets of stream data at the upstream and downstream cross sections are available from the U.S. Army Corps of

Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained during the period between December 1999 and March 2000; a total of only 4 months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period were calculated and are presented in **Table 3**. Note that because there is no observation at the point where contaminated groundwater flow discharges into the Goose Prairie Creek, average values between upstream and downstream flow were used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 2.5 cubic feet per second (cfs) is derived (**Figure 5**). Then:

$$DF = (6.283 \times 10^{-5} + 2.5) / (6.283 \times 10^{-5}) = 39,791 \quad \text{Equation J4}$$

The mixing concentrations for the three chemicals in Goose Prairie Creek are:

Trichloroethene:	$567.5/39791 = 0.014 \mu\text{g/L}$
Vinyl chloride:	$16.8/39791 = 4.22 \times 10^{-4} \mu\text{g/L}$
Perchlorate:	$17840/39791 = 0.448 \mu\text{g/L}$

The above mixing calculation results (summarized in **Table 2**) show that concentrations of TCE (0.014 $\mu\text{g/L}$), VC ($4.22 \times 10^{-4} \mu\text{g/L}$), and perchlorate (0.448 $\mu\text{g/L}$) in Goose Prairie Creek are much lower than their respective MCLs or the action level; hence, the COC levels in groundwater are protective of surface water.

Field Confirmation

All the maximum concentrations of COCs occurred at 50WW02, which is 132 feet away from the Goose Prairie Creek. The model assumes a plume area of 100 ft x 100 ft with the maximum concentrations of each contaminant. There is no downgradient well before approaching the creek. For this reason, no evaluation of contaminant concentration at a lateral location downgradient was attempted to provide field confirmation of the model.

4.0 *References*

References are provided in the main document, Section 8.0.

Table 1
Maximum Concentrations and Chemical Properties for COCs at LHAAP-50

Chemical	Maximum Observed Concentration in GW (µg/L)	MCL (µg/L)	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
Trichloroethene	22,000.0	5.0	100.0	0.1	0.1	1.00E-04	4.5	0.154
Tetrachloroethene	35.0	5.0	155.0	0.1	0.155	1.55E-04	2	0.347
Vinyl Chloride	100.0	2.0	11.0	0.1	0.011	1.10E-05	3.4	0.087
1,2-Dichloroethane	98.0	5.0	31.6	0.1	0.0316	3.16E-05	1	0.693
Perchlorate ⁽³⁾	18,000.0	4.0 ⁽⁴⁾	N/A	---	---	---	N/A	N/A

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard et al., 1991, "Environmental Degradation Rates"

(3) No data available, assumed no degradation and no water-soil partitioning

(4) TCEQ interim action level

% percent

µg/L micrograms per liter

cm³/g cubic centimeters per gram

foc fraction organic carbon

Kd water-soil partition coefficient

Koc carbon-water sorption coefficient

m³/kg cubic meters per kilogram

N/A not available

Table 2
Summary of TCE, PCE, VC, 1,2-DCA, and Perchlorate Concentrations
at Goose Prairie Creek, LHAAP-50

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Goose Prairie Creek (feet)	Source Release Rate* (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration at Goose Prairie Creek (µg/L) (DF)	MSC Based on DF at Groundwater & Goose Prairie Creek (µg/L)	Mixing Concentration in Goose Prairie Creek (µg/L)	Overall MSC at Point of Discharge into Goose Prairie Creek (µg/L)
Trichloroethene	5.0	100 x 100	22,000.0	132	21.8	1	567.5 (11.5 years) (38.8)	194	0.014	7,857,143
Tetrachloroethene	5.0	100 x 100	35.0	132	0.035	7.5	0 (Infinity)	Infinity	NE	NE
Vinyl Chloride	2.0	100 x 100	100.0	132	0.099	1.5	16.8 (12.5 years) (5.95)	11.9	4.22x10 ⁻⁴	473,934
1,2-Dichloroethane	5.0	100 x 100	98.0	132	0.097	1.5	0 (Infinity)	Infinity	NE	NE
Perchlorate	4 ⁽¹⁾	100 x 100	18,000.0	132	17.840	1.0	17,840 (31.5 years) (1.01)	4.04	0.448	160,714

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 10 feet.

* Instantaneous source release rate in kg = maximum source concentration x porosity x source area x thickness of layer

⁽¹⁾ Texas interim action level

µg/L micrograms per liter

DF dilution/attenuation factor

kg kilogram

MCL maximum contaminant level

mg/L milligrams per liter

MSC medium specific concentration

NE not evaluated due to concentration in groundwater already below MCL, or action level at point of entry

Table 3
Calculation of Flow Discharge in Goose Prairie Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (feet ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.10830	0.22081	1.44906	4.88410	2.80	4.20	4.0574	20.5132	12.2853
	10 - 16	0.11651	0.30483	0.48774	2.94988	3.21	6.87	1.5656	20.2657	10.916
	17 - 23	0.06315	0.37523	0.45438	2.12994	2.10	8.56	0.9542	18.2323	9.593
	24 - 30	0.06315	0.36534	0.45438	14.99560	2.10	7.88	0.9542	118.1653	59.560
Jan-00	1 - 7	0.02700	0.36224	0.21000	7.10767	1.05	7.98	0.2205	56.7192	28.470
	8 - 14	0.12681	0.44958	0.24389	11.82963	3.45	18.63	0.8414	220.3860	110.614
	15 - 21	0.03749	0.36559	0.03032	11.51831	1.41	8.35	0.0428	96.1779	48.110
	22 - 28	0.06279	0.42399	0.80813	14.08148	2.08	17.56	1.6809	247.2708	124.476
Feb-00	1 - 7	0.09417	0.42572	0.12182	9.59478	2.65	20.51	0.3228	196.7889	98.556
	8 - 14	0.05132	0.37422	0.04973	6.47123	1.75	8.01	0.0870	51.8346	25.961
	15 - 21	0.03763	0.37675	0.04530	0.53829	1.48	9.24	0.0670	4.9738	2.520
	22 - 28	0.14625	0.48311	0.35183	1.14280	4.45	20.51	1.5656	23.4388	12.502
Mar-00	1 - 7	0.10288	0.37274	0.16989	0.50621	2.79	7.95	0.4740	4.0244	2.249
	8 - 14	0.20995	0.58798	0.48053	1.13559	6.10	21.55	2.9312	24.4720	13.702

Notes and Abbreviations:

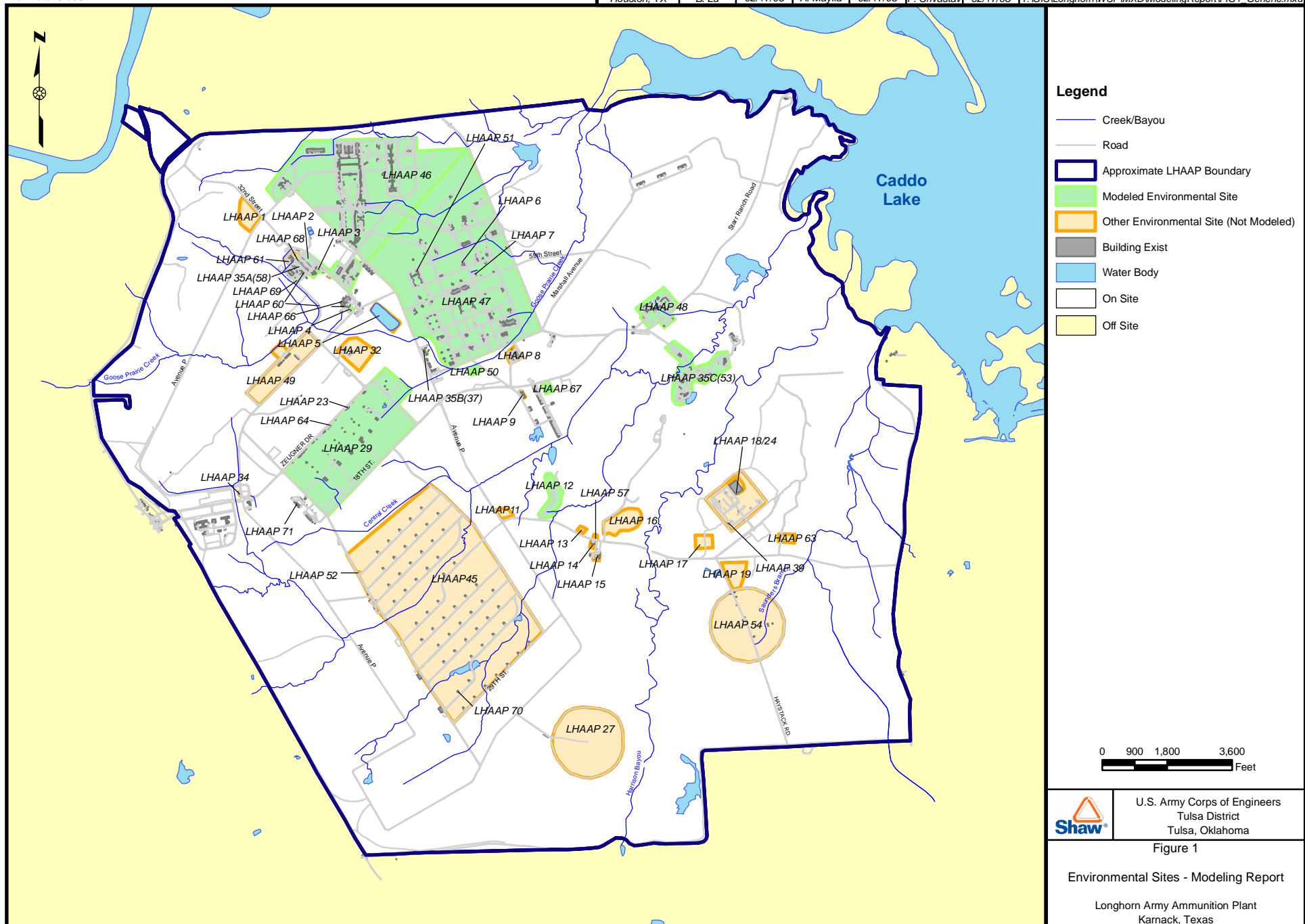
Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs cubic feet per second

Plot Date: 02/05

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\MXD\ModelingReport\FIG1 Generic.mxd



U.S. Army Corps of Engineers
Tulsa District
Tulsa, Oklahoma

Figure 1

Environmental Sites - Modeling Report

Longhorn Army Ammunition Plant
Karnack, Texas

Figure 2 - Appendix J
Trichloroethene Concentrations in Groundwater at Goose Prairie Creek
(132 feet from Source)
LHAAP-50, Longhorn Army Ammunition Plant, Texas

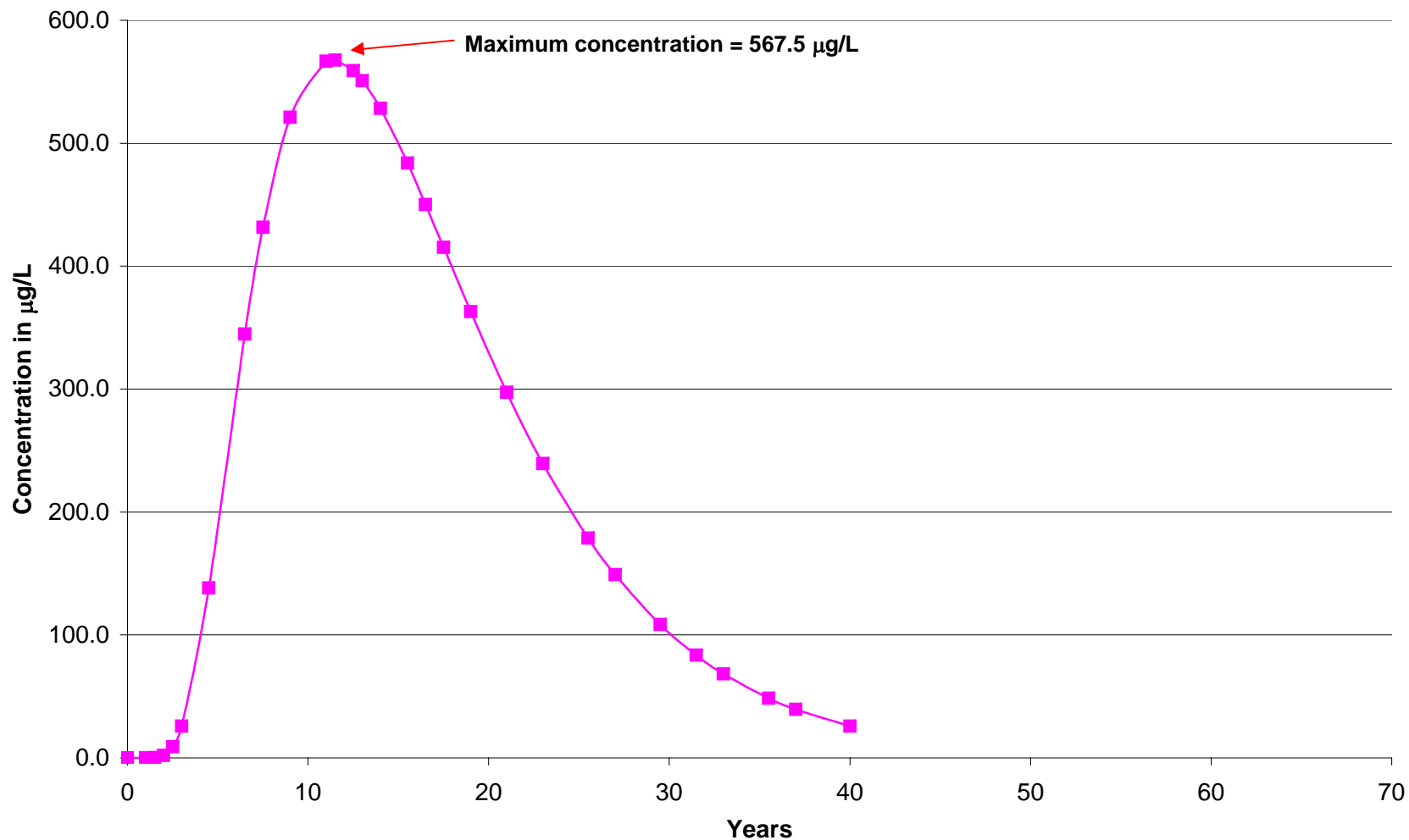


Figure 3 - Appendix J
Vinyl Chloride Concentrations in Groundwater at Goose Prairie Creek
(132 feet from Source)
LHAAP-50, Longhorn Army Ammunition Plant, Texas

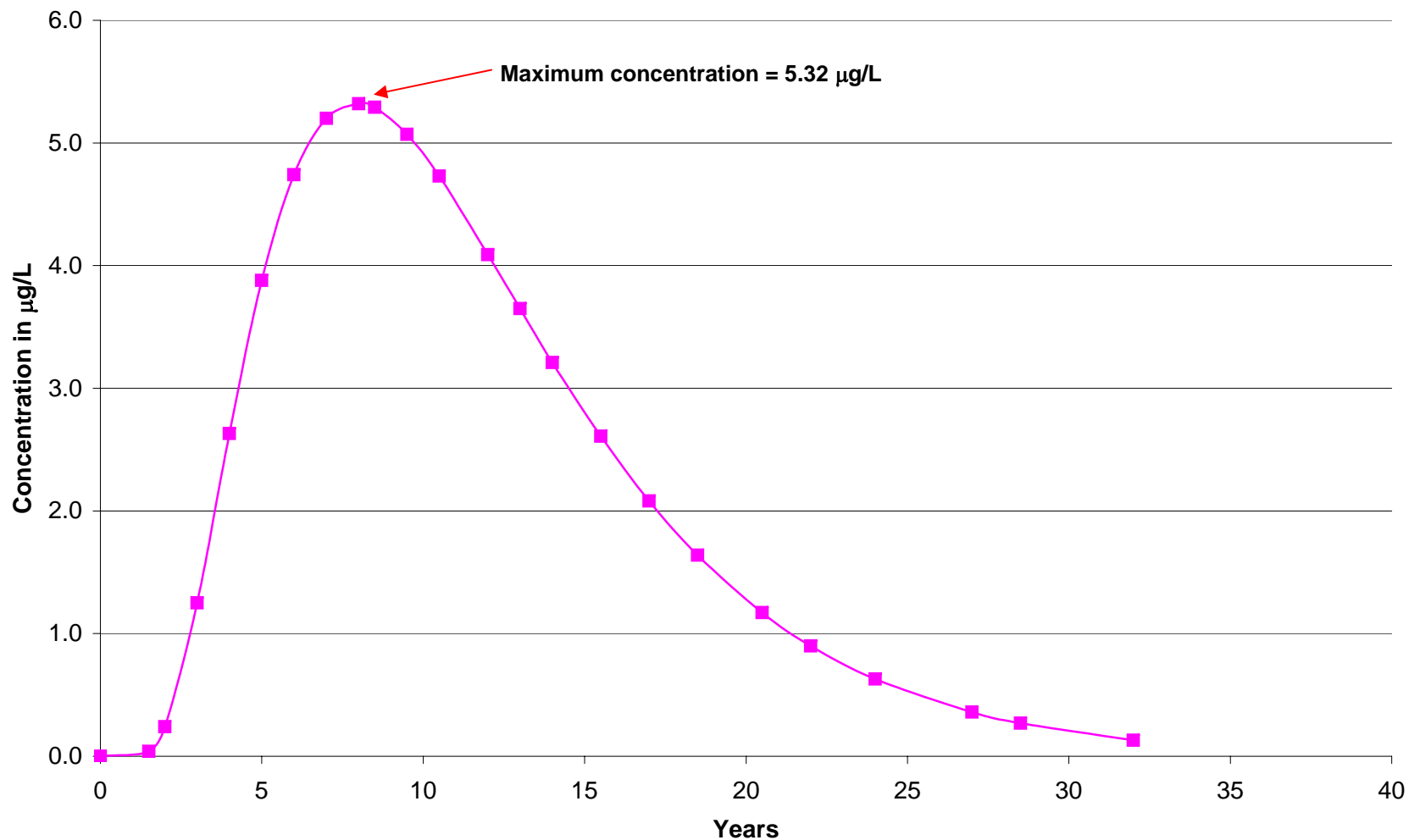


Figure 4 - Appendix J
Perchlorate Concentrations in Groundwater at Goose Prairie Creek
(132 feet from Source)
LHAAP-50, Longhorn Army Ammunition Plant, Texas

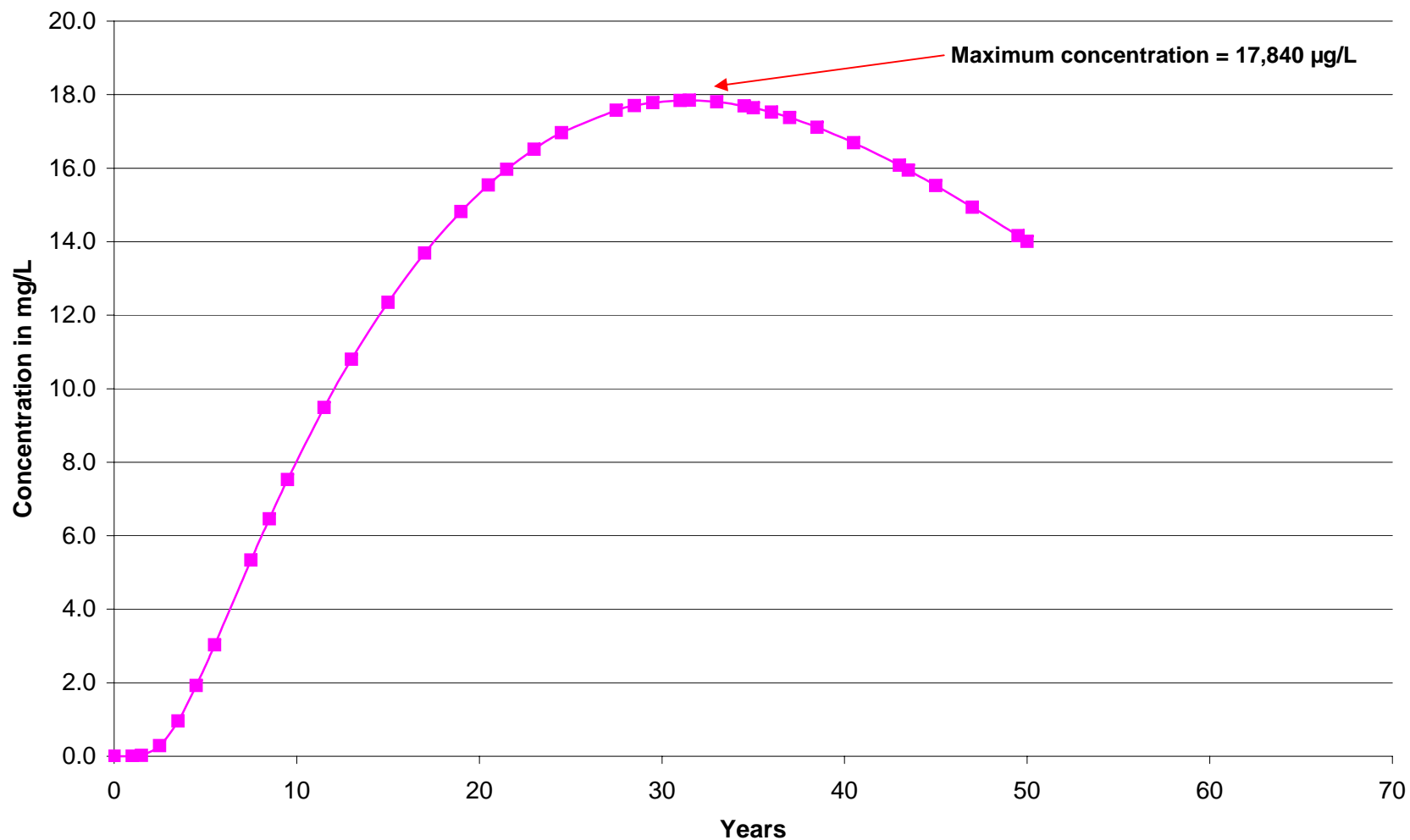
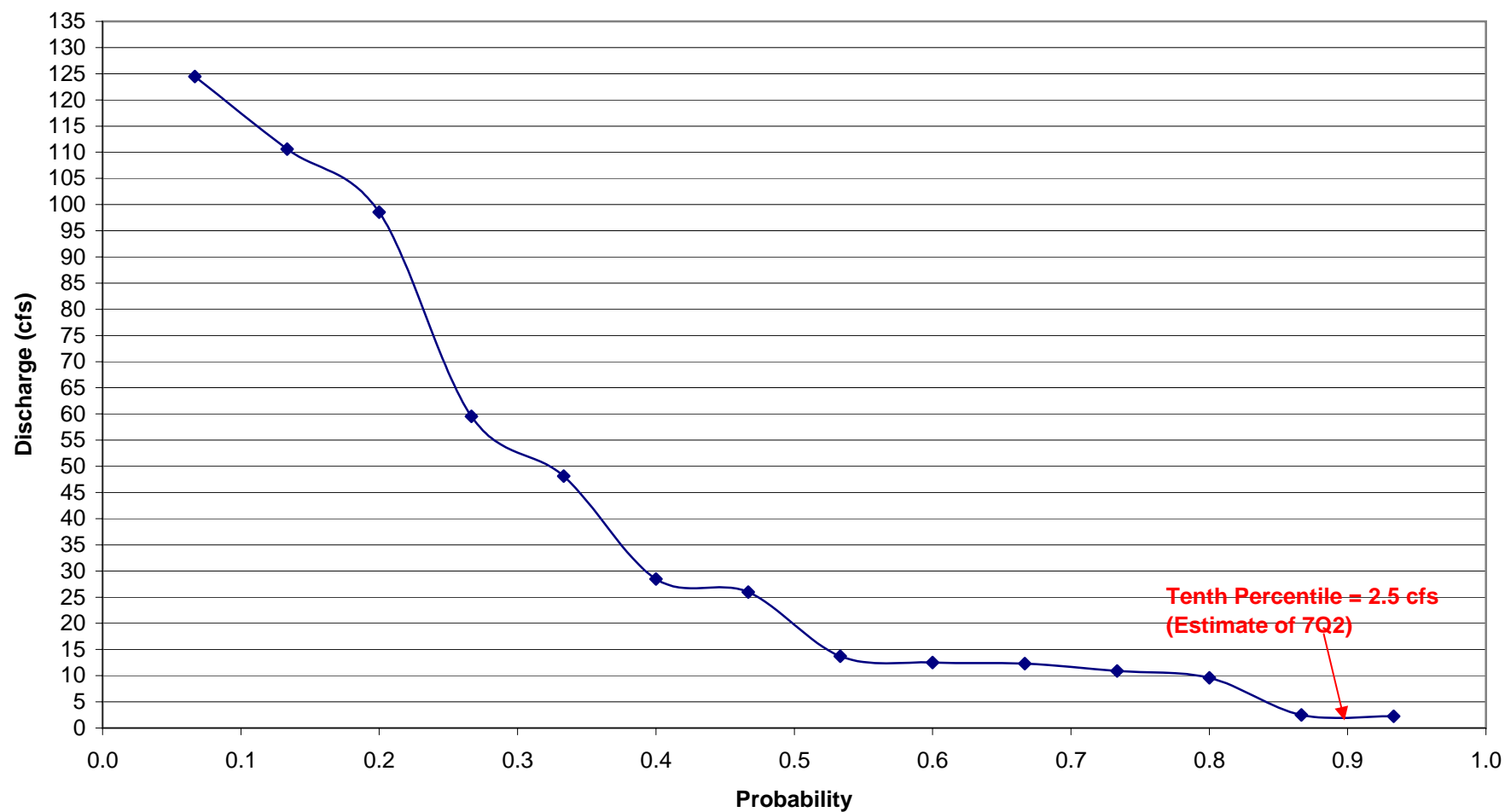


Figure 5 - Appendix J
Low Flow Analysis
Probability vs Flow Discharge for Goose Prairie Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix K

***LHAAP-67 Calculation of Maximum Concentrations and
Dilution Factors of Contaminants Discharged to Central
Creek***

Table of Contents

1.0	Introduction	1-1
2.0	Input Parameters and Assumptions	2-1
3.0	Simulation and Results	3-1
3.1	Instantaneous Source Scenario.....	3-1
3.2	Continuous Source Scenario	3-1
4.0	References	4-1

List of Tables

Table 1	Chemical Properties for LHAAP-67 Groundwater Fate and Transport Modeling
Table 2	Summary of 1,1-DCE, 1,2-DCA, 1,1,1-TCA, 1,1,2-TCA, and TCE Concentrations at Central Creek (867 feet Downgradient from Source)
Table 3	Calculation of Flow Discharge in the Central Creek (Data Collected from December 1, 1999 to March 15, 2000)

List of Figures

Figure 1	Environmental Sites – Modeling Report
Figure 2	Low Flow Analysis, Probability vs. Flow Discharge for Central Creek Based on December 1999 to March 2000 Flow Derivation

1.0 Introduction

LHAAP-67 is located approximately at the center of Longhorn Army Ammunition Plant with LHAAP-12 to the south and LHAAP-8 to the northwest (**Figure 1**). This site was referred to as the aboveground storage tank area where seven aboveground tanks stored fuel oil, kerosene, and solvents.

The chemicals of concern (COC) in the groundwater at LHAAP-67 are 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), 1,1,1-trichloroethane (1,1,1-TCA), 1,1,2-trichloroethane (1,1,2-TCA), and trichloroethene (TCE), detected at maximum concentrations of 380 µg/L, 27.0 µg/L, 1,800 µg/L, 33.0 µg/L and 6.3 µg/L, respectively. The purpose of the following evaluation is to calculate the dilution factor of each contaminant at the location where they may enter the nearest surface body.

There are two streams in the vicinity of LHAAP-67: Central Creek to the southeast and Goose Prairie Creek to the northwest. Contaminants in the groundwater are most likely to travel to Central Creek rather than to Goose Prairie Creek due to the easterly and southeasterly groundwater flow from LHAAP-67 based on December 1998 groundwater level measurements (Figure 3A-Appendix A; Figure 2-1 in Jacobs, 2002a). The distance from LHAAP-67 to Central Creek is approximately 867 feet (**Figure 1**).

The purpose of this calculation is to estimate the maximum concentrations and dilution factors (DFs) of the five COCs at the point of entry (POE) of the groundwater into Central Creek, and to develop the groundwater medium-specific concentrations (MSCs) by multiplying these dilution factors with the maximum contaminant levels (MCLs).

In order to calculate the maximum concentrations of the contaminants and the time of travel at the POE at Central Creek, AT123D was used.

2.0 *Input Parameters and Assumptions*

The groundwater model at LHAAP-67 was based on the following assumptions and considerations:

- Instantaneous and continuous source scenarios were assumed. When there is no leachate contribution from the vadose zone soil to the groundwater, the only source is the current plume. This plume can be treated as an instantaneous source. On the other hand, leachate from soil may still be probable at LHAAP-67. In this case, leachate was considered as a continuous source and may replenish the contaminants in groundwater over time. Therefore, in the current modeling, both instantaneous and continuous source scenarios were considered because of the uncertainty of the cases. For the continuous source scenario, it was conservatively assumed that the maximum concentrations of contaminants remained constant throughout the entire simulation period to account for the constant continuous source.
- The source area was assumed conservatively to be the plume area. The dimensions of the plume are assumed to be: 200 feet (east-west) by 300 feet (north-south) by 13.5 feet in depth (i.e., shallow sand thickness) for all the contaminants.
- Shallow sand thickness. Because no geologic cross sections were constructed for this site, the geologic cross sections in the most southern end of LHAAP-47 were used (Figures 9-2 through 9-6, Jacobs 2002a). The thickness of the shallow water bearing zone consisting of sand is in the range of 12 to 15 feet. Therefore, an average depth of 13.5 feet was used. It was assumed that the contaminant source in this shallow zone extended to the entire depth of 13.5 feet.
- The contaminant release rates for the two source scenarios. For instantaneous release, the release rate is actually the mass of contaminant within the plume with maximum concentration (in kg) – a conservation estimation. For the continuous source scenario, the release rate was estimated based on the maximum concentration in the plume multiplied by the groundwater velocity and plume area (in kg/hr). The continuous release rate was assumed to be constant for a 100 year period. The chemical properties and the calculated contaminant release mass and the release rate for all the COCs are presented in **Table 1** and **Table 2**, respectively.

The contaminant source in the saturated zone was assumed to reach the full thickness of the aquifer (i.e., 13.5 feet).

The properties of the shallow water bearing zone used in the model were as follows:

- Average hydraulic conductivity: 5.21×10^{-3} cm/sec (Jacobs, 2002a);
- Hydraulic gradient: 0.0033 feet/feet (based on potentiometric surface map in Jacobs, 2001b)

- Effective porosity: 0.25 assumed)
- α_x = longitudinal groundwater dispersivity (feet) = $x \times 0.1$ (ASTM, E-1739-95, Table x3.1, 1995) where x is the travel distance of contaminants, assumed to be the distance from the source to the Central Creek.
- α_y = transverse groundwater dispersivity (feet) = $\alpha_x / 3$ (ASTM, E-1739-95, Table x3.1, 1995)
- α_z = vertical groundwater dispersivity (feet) = $\alpha_x / 20$ (ASTM, E-1739-95, Table x3.1, 1995)

3.0 Simulation and Results

The simulation time step was one year with a total simulation period of 100 years which was long enough to capture the maximum concentrations occurring at the POE into Central Creek. Computer simulation results were evaluated at the POE. These results include the time when the COCs reach the POE, the time the concentrations reach its peak, the maximum concentrations at this location, the DFs and the MSCs based on DFs and MCLs. **Table 2** presents a summary of these results for both the instantaneous and continuous source scenarios.

3.1 Instantaneous Source Scenario

The DFs calculated for this scenario at the POE are infinity, 450, 753, 143.5, and 48.5 for 1,1-DCE, 1,2-DCA, 1,1,1-TCA, 1,1,2-TCA and TCE, respectively. All maximum concentrations under this scenario are below their respective MCLs at the POE which is the location where groundwater discharges into the creek. No further dilution calculation in the creek is needed for this scenario.

3.2 Continuous Source Scenario

The continuous source scenario yielded much higher concentrations that exceed MCLs at the POE for some of the COCs as shown in **Table 2**. Except for 1,1-DCE and 1,2-DCA, the maximum concentrations of all other contaminants are 240.6 µg/L, 23.7 µg/L, and 21.6 µg/L for 1,1,1-TCA, 1,1,2-TCA, and TCE, respectively. Calculation of dilution of these contaminants in the creek was required.

The DFs of the above mentioned four contaminants after mixing with surface water in the Central Creek are calculated based on the dilution factor of the mixing calculated below:

$$DF = \frac{Q_{GW} + Q_{CC}}{Q_{GW}} \quad \text{Equation K1}$$

Where:

Q_{CC} and Q_{GW} are the flow rates in the Central Creek and in groundwater, respectively.

$$Q_{GW} = U_{gw} \times \delta_p \times L_m \quad \text{Equation K2}$$

Where U_{gw} , δ_p and L_m are the approaching groundwater seepage velocity, the thickness and width of the plume approaching surface water. U_{gw} ($= Ki/n$) is 71.08 feet/year, calculated based on the hydraulic conductivity of 5.206×10^{-3} cm/sec, hydraulic gradient of 0.0033 and the effective

porosity of 0.25. δ_p is 13.5 feet and L_m is unknown at the intersection but can be conservatively assumed to be the same width as the source, which is 200 feet. Then:

$$Q_{GW} = 71.08 / (365 \times 86400) \times 13.5 \times 200 = 6.1 \times 10^{-3} \text{ ft}^3/\text{s} \quad \text{Equation K3}$$

Calculation of Q_{CC} has to be based on the 7Q2 stream flow analysis. The 7Q2 is the low flow at the POE, defined as the flow discharge in seven consecutive days that occurs once every two years, statistically. At Central Creek, two sets of stream data at the upstream and downstream cross sections are available from the U.S. Army Corps of Engineers. These data sets include the velocity data and the gauge readings (i.e., depths of water) obtained during the period between December 1999 and March 2000; a total of only 4 months. Flow discharge data were not available. Based on these data, the average flow discharges in every consecutive 7-day period were calculated and are presented in **Table 3**. Note that because there is no observation at the point where contaminated groundwater flow discharges into the Central Creek, average values between upstream and downstream flow were used. Because the derived flow data are less than five continuous years, TCEQ (TCEQ, 2003) requires that the 10th percentile flow be used as an estimate of 7Q2. Based on these fourteen 7-day flow data, the 7Q2 is analyzed and the 10th percentile flow of 1.0 cubic feet per second (cfs) is derived (**Figure 2**). Then:

$$DF = (6.1 \times 10^{-3} + 1.0) \div (6.1 \times 10^{-3}) = 164.9 \quad \text{Equation K4}$$

The mixing concentrations for the four contaminants in Central Creek are:

$$1,2\text{-DCA:} \quad 3.91/164.9 = 0.024 \text{ } \mu\text{g/L}$$

$$1,1,1\text{-TCA:} \quad 240.6/164.9 = 1.459 \text{ } \mu\text{g/L}$$

$$1,1,2\text{-TCA:} \quad 23.7/164.9 = 0.144 \text{ } \mu\text{g/L}$$

$$\text{TCE:} \quad 21.6/164.9 = 0.131 \text{ } \mu\text{g/L}$$

These concentrations are all lower than their respective MCLs. The mixing concentrations and the overall MSCs for all the contaminants are presented in **Table 2**.

Field Confirmation

The initial plume covers an area of 200 ft by 300 ft. There is no downgradient well from the source area before approaching the creek. For this reason, no evaluation of contaminant concentration at a lateral location downgradient was attempted to provide field confirmation of the model.

4.0 References

References are provided in the main document, Section 8.0.

Table 1
Chemical Properties for LHAAP-67 Groundwater Fate and Transport Modeling

Chemical	Koc ⁽¹⁾ cm ³ /g	foc %	Kd cm ³ /g	Kd m ³ /kg	Half-life years ⁽²⁾	Degradation Rate (1/year)
1,1-Dichloroethene	61.7	0.1	0.0617	6.17E-05	0.362	1.917
1,2-Dichloroethane	31.6	0.1	0.0316	3.16E-05	1	0.694
1,1,1-Trichloroethane	125.9	0.1	0.126	1.26E-04	1.5	0.462
1,1,2-Trichloroethane	70.8	0.1	0.0708	7.08E-05	2	0.347
Trichloroethene	100	0.1	0.1	1.00E-04	4.5	0.154

Notes and Abbreviations:

Sources: (1) Montgomery, 2000, "Groundwater Chemicals - Desk Reference (Third Edition)"

(2) Howard, et al., 1991, "Environmental Degradation Rates"

cm³/g cubic centimeters/gram

% percent

m³/kg cubic meters/kilogram

Table 2
Summary of 1,1-DCE, 1,2-DCA, 1,1,1-TCA, 1,1,2-TCA, and TCE Concentrations
at Central Creek (867 feet Downgradient from Source)

(a) Instantaneous Source Scenario

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Central Creek (feet)	Source Release Rate* (kg)	Years Contaminant Starts to Appear (years)	Maximum Concentration at Central Creek (mg/l) (DF)	MSC Based on DF at Groundwater & Central Creek (µg/L)
1,1-Dichloroethene	7.0	200 x 300	380	867	3.1	Infinity	0 (Infinity)	Infinity
1,2-Dichloroethane	5.0	200 x 300	27.0	867	0.22	2.0	0.06 (450)	2250
1,1,1 - Trichloroethane	200.0	200 x 300	1,800	867	14.48	2.0	2.39 (6 Years) (753)	150628
1,1,2 - Trichloroethane	5.0	200 x 300	33.0	867	0.27	4.0	0.23 (6 years) (143.5)	717
Trichloroethene	5.0	200 x 300	6.3	867	0.05	4.0	0.13 (8 Years) (48.5)	242

(b) Continuous Source Scenario

Source Type	MCL (µg/L)	Source Area (north-south x east-west) (feet x feet)	Maximum Observed Source Concentration (µg/L)	Distance to Central Creek (feet)	Source Release Rate* (kg/hr)	Years Contaminant Starts to Appear (years)	Maximum Concentration in GW at Central Creek (mg/l) (DF)	MSC Based on DF at Groundwater & Central Creek (µg/L)	Mixing Concentration at Point of Discharge into Central Creek (µg/L)	MSC Based on DF at Point of Discharge into Central Creek (µg/L)
1,1-Dichloroethene	7.0	200 x 300	380	867	5.243E-03	2.0	0.15(8 years) (2533)	14,778		
1,2-Dichloroethane	5.0	200 x 300	27.0	867	3.730E-04	2.0	3.9 (12 years) (6.91)	34.5	0.024	5625
1,1,1 - Trichloroethane	200.0	200 x 300	1,800	867	2.480E-02	2.0	240.6 (29 Years) (7.5)	1500	1.459	246744
1,1,2 - Trichloroethane	5.0	200 x 300	33.0	867	4.550E-04	2.0	23.7 (49 years) (1.4)	6.95	0.144	1146
Trichloroethene	5.0	200 x 300	6.3	867	8.690E-05	3.0	21.6 (39 Years) (0.29)	1.46	0.131	240

Notes and Abbreviations:

All the sources are instantaneous and extend across the entire aquifer thickness of 13.5 feet.

* Instantaneous source release in kg = maximum source concentration x pore space volume in source area (assuming a total porosity of 0.35)

Continuous source release rate in kg/hr = maximum source concentration x groundwater seepage velocity x source area

DF dilution/attenuation factor

MSC medium specific concentration

Table 3
Calculation of Flow Discharge in the Central Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (ft)		Measured Velocity (ft/s)		Cross Sectional Area (ft ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.09341	1.11074	0.11183	1.29100	6.10	6.31	0.6822	8.1462	4.4142
	10 - 16	0.07876	1.48660	0.14567	0.25542	4.40	7.30	0.6409	1.8646	1.253
	17 - 23	0.03000	1.46344	0.11000	0.73705	2.00	7.25	0.2200	5.3436	2.782
	24 - 30	0.03000	1.32520	0.11000	0.23729	2.00	7.00	0.2200	1.6610	0.941
Jan-00	1 - 7	0.03000	1.06090	0.11000	0.29642	3.90	11.90	0.4290	3.5274	1.978
	8 - 14	0.07554	1.62076	0.13253	0.19877	2.50	10.80	0.3313	2.1467	1.239
	15 - 21	0.03000	1.48365	0.07000	0.15027	2.50	7.20	0.1750	1.0819	0.628
	22 - 28	0.04400	1.36087	0.08400	3.31644	8.50	11.00	0.7140	36.4808	18.597
Feb-00	1 - 7	0.05970	1.63820	0.05752	0.54047	2.00	6.12	0.1150	3.3077	1.711
	8 - 14	0.03500	1.51571	0.03000	0.25153	4.20	11.70	0.1260	2.9429	1.534
	15 - 21	0.03500	1.44892	0.03000	1.64454	2.00	7.26	0.0600	11.9394	6.000
	22 - 28	0.04400	1.55024	0.08400	0.25240	2.80	7.15	0.2352	1.8047	1.020
Mar-00	1 - 7	0.06586	2.07625	0.05766	3.62250	4.10	17.90	0.2364	64.8428	32.540
	8 - 14	0.19663	2.40898	0.28986	2.59353	12.00	25.30	3.4783	65.6163	34.547

Notes:

Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Lu	02/17/05	A. Mayila	02/17/05	P. Srivastav	02/17/05	T:\GIS\Longhorn\WSP\WMD\Modeling\Report\FIG1_Generic.mxd

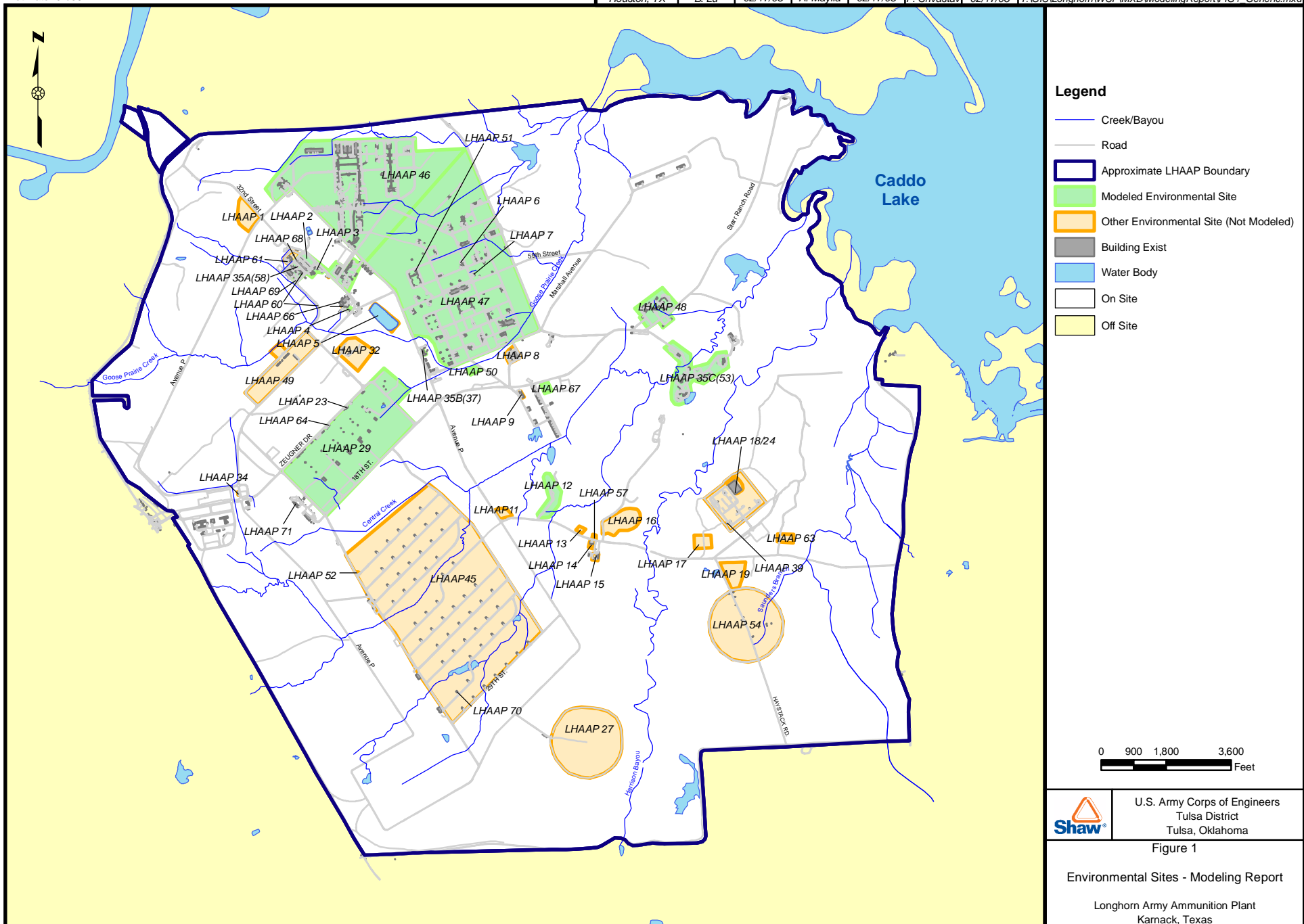
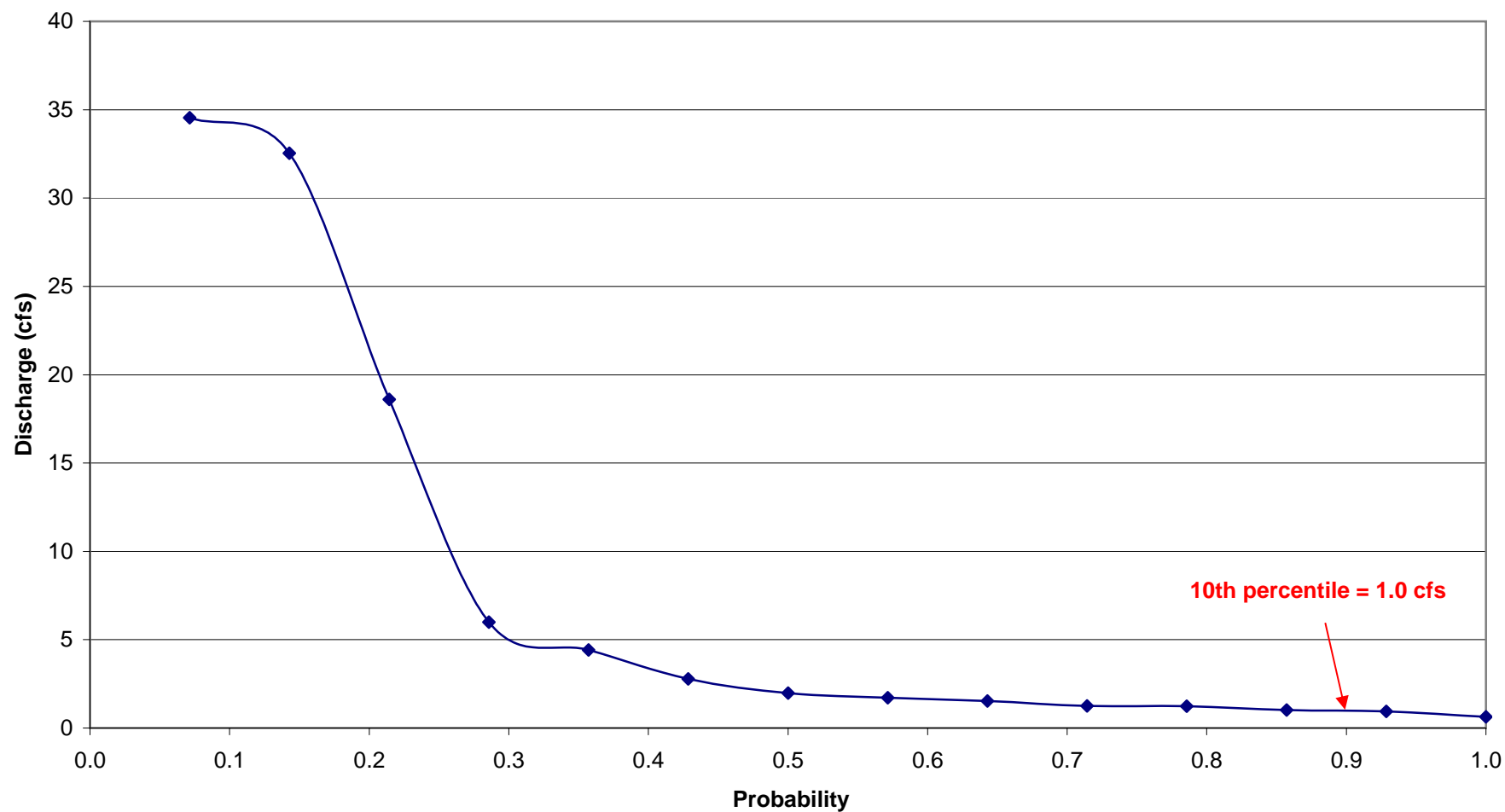


Figure 2 - Appendix K
Low Flow Analysis
Probability vs Flow Discharge for Central Creek
Based on December 1999 to March 2000 Flow Derivation



Appendix L

***Additional Evaluations of Chemicals in Soil at
LHAAP-35A(58), -46, and -48***

Table of Contents

List of Tables	ii
List of Figures	ii
List of Attachments	ii
1.0 Introduction	1-1
2.0 Modeling	2-1
2.1 LHAAP-35A(58)	2-1
2.1.1 Leachate Modeling	2-1
2.1.1.1 Assumptions and Input Parameters	2-1
2.1.1.2 Simulation and Results	2-2
2.1.2 Soil Concentration Protective of Sediment and Surface Water	2-3
2.1.2.1 Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Sediment	2-3
2.1.2.2 Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Surface Water (^{SW} Soil MSC)	2-4
2.1.3 Summary and Conclusion	2-6
2.2 LHAAP-46	2-6
2.2.1 Leachate Modeling	2-6
2.2.2 Soil Concentrations Protective of Sediment and Surface Water	2-7
2.2.2.1 Bis(2-exylhexyl)phthalate Concentration in Erodable Soil Protective of Sediment (^{Sed} Soil MSC)	2-7
2.2.2.2 Bis(2-exylhexyl)phthalate Concentration in Erodable Soil Protective of Surface Water (^{SW} Soil MSC)	2-7
2.2.3 Results	2-9
2.3 LHAAP-48	2-9
2.3.1 Leachate Modeling	2-10
2.3.1.1 Assumptions and Input Parameters	2-10
2.3.1.2 Simulation Results	2-10
2.3.2 Soil Concentration Protective of Sediment and Surface Water	2-10
2.3.2.1 Vinyl Chloride and Tetrachloroethene Concentrations in Erodable Soil Protective of Sediment	2-11
2.3.2.2 Vinyl Chloride and Tetrachloroethene Concentrations in Erodable Soil Protective of Surface Water	2-12
2.3.3 Results	2-14
3.0 References	3-1

List of Tables

Table 1	Input Parameters and Results for Additional Calculations of Soil Concentrations Protective of Sediment and Surface Water
Table 2	Input Parameters for Additional Modeling of Soil Concentrations Protective of Groundwater
Table 3	Calculation of Flow Discharge in Goose Prairie Creek (Data Collected from Dec. 1, 1999 to March 15, 2000)
Table 4	Calculation of Flow Discharge in Central Creek (Downstream) (Data Collected from Dec. 1, 1999 to March 15, 2000)

List of Figures

Figure 1	Low Flow Analysis, Probability vs. Flow Discharge for Goose Prairie Creek based on December 1999 to March 2000 Flow Derivation
Figure 2	Mixing Concentration of VC in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-48
Figure 3	Mixing Concentration of PCE in Groundwater Contributed by Soil Leachate Condition at the Source Area, LHAAP-48
Figure 4	Low Flow Analysis – Probability vs Flow Discharge for Central Creek (Downstream)

List of Attachments

Attachment A	Computer Printout for the Mixing Concentration of Bis(2-ethylhexyl)phthalate in Groundwater Caused by Leachate from Soil at LHAAP-35A(58)
--------------	---

1.0 Introduction

The fate and transport for three chemicals of concern (COCs) in soil at three sites (LHAAP-35A[58], -46, and -48) was evaluated as follows:

LHAAP-35A(58): 1) Calculations of bis(2-ethylhexyl)phthalate transport by eroded soil to nearby Goose Prairie Creek; and 2) leaching of bis(2-ethylhexyl)phthalate from soil to groundwater and from groundwater to Goose Prairie Creek.

LHAAP-46: Calculations of bis(2-ethylhexyl)phthalate transported by eroded soil to Goose Prairie Creek – Middle.

LHAAP-48: 1) Calculations of vinyl chloride and tetrachloroethane transport by eroded soil to Central Creek; and 2) leaching of vinyl chloride and tetrachloroethane from soil to groundwater and from groundwater to Central Creek.

The approach to develop soil concentrations protective of sediment and surface water is described in the Technical Memorandum (Shaw Environmental, 2004) and the following sections. **Tables 1** and **2** present summaries of input parameters for the calculations.

2.0 Modeling

2.1 LHAAP-35A(58)

Elevated bis(2-ethylhexyl)phthalate concentrations were detected in soil at 200,000 µg/kg at sampling location LHS-SH-05 at a depth interval of 1.0 to 2.0 feet below land surface (Jacobs 2002a). Due to the elevated concentration of bis(2-ethylhexyl)phthalate in soil, its vertical downward transport and horizontal pathway transported by eroded soil were modeled to evaluate its contribution to groundwater, surface water and sediments.

The surface water body closest to LHAAP-35A(58) is Goose Prairie Creek, approximately 120 feet to the west of the site. Goose Prairie Creek flows from west to east, southeast and northeast to Caddo Lake. Generally, groundwater flows in the same direction as surface water. Contaminant particles in the groundwater at LHAAP-35A(58) will not travel to the southwest or west but to the east until they reach Goose Prairie, at a distance ranging from 6,319 feet (straight line) to 8,000 feet downgradient of the site.

The maximum bis(2-ethylhexyl)phthalate concentrations in sediment and in surface water, as well as the medium-specific concentrations (MSCs) in the soil, that are protective of sediment and surface water were developed.

2.1.1 Leachate Modeling

A VLEACHSM (Dynamac Corporation 1995; ASTM, 1999) model was employed to obtain the leachate mixing concentration hydrographs of bis(2-ethylhexyl) in the groundwater at LHAAP-35A(58).

2.1.1.1 Assumptions and Input Parameters

Because of the uncertainty of the input parameters, conservative values were used and assumptions were made as described below:

- **Contaminant Source.** Because of the uncertainty of the time bis(2-ethylhexyl)phthalate continues to dissolve and to be released to groundwater, two scenarios were considered in the modeling using VLEACHSM: continuous constant source release for 10 years and 100 years.
- **Source Area.** bis(2-ethylhexyl)phthalate was detected at sampling location LHS-HS-05 with a maximum concentration of 200,000 µg/kg in soil. The simulated soil column with bis(2-ethylhexyl)phthalate source was assumed 5 feet by 5 feet in area and 12 feet in depth at LHS-HS-05 only, applying the maximum soil concentration of 200,000 µg/kg at a depth of 1 to 2 feet. The simulated results were then applied to the entire area of 600 feet (east-west) by 500 feet (north-south) as affected area in .

- **Depth to Groundwater.** The land surface elevation based on Figure 2-2 in the main report is approximately 216 feet mean sea level (msl). The average groundwater elevation measured in December 1998 at LHAAP-35A(58) was 204 feet (msl). Therefore the depth to groundwater is 12 feet.
- **Chemical Parameters.** The water-soil partition coefficient (k_d) of bis(2-ethylhexyl)phthalate is as high as $87 \text{ cm}^3/\text{g}$ based on a very high value of organic carbon partition coefficient of $87096 \text{ cm}^3/\text{g}$ (Montgomery, 2000). The half-life for bis(2-ethylhexyl)phthalate is 1.1 years (Howard et al., 1991). The Henry's law constant, diffusivity in air and solubility for bis(2-ethylhexyl)phthalate are $4.18\text{E-}6$ (dimensionless), $0.0351 \text{ cm}^2/\text{sec}$, and $350 \text{ }\mu\text{g/L}$, respectively (Montgomery, 2000; Oak Ridge National Laboratory, 2004).
- **Dispersivities.** The longitudinal dispersivity was calculated based on the following equation (Dynamac Corporation, 1995):

$$\alpha_L = 1.072 \times 10^{-1} L_u^{0.584} \quad (L_u = 12 \text{ feet} - < 6.562, \text{ depth of the column})$$

$$= 0.458 \text{ feet}$$

and the vertical dispersivity $\alpha_v = 0.3 \alpha_L = 0.153 \text{ feet}$

- **Darcy's velocity.** Darcy's velocity (D_v) is required by VLEACHSM.

$$D_v = ki \quad (k = \text{hydraulic conductivity and } i = \text{hydraulic gradient})$$

Average hydraulic conductivity, (k) based on the slug tests at LHAAP-35A(58) was estimated to be $6.36 \times 10^{-4} \text{ cm/sec}$ (Jacobs 2002a).

The hydraulic gradient of 0.0072 feet/feet was based on the potentiometric surface map from December 1998 (Jacobs 2001b). Therefore, $D_v = 4.74 \text{ feet/year}$.

- **Recharge.** This input parameter has a high degree of uncertainty. Because the soil at the site is mainly clayey material (silty clay and clay) in the shallow subsurface, infiltration rate is very low. In this model, two scenarios of recharge to groundwater were assumed: 0.5 inch/year and 1.0 inch/year.

2.1.1.2 Simulation and Results

The simulated result of the mixing concentration of bis(2-ethylhexyl)phthalate in groundwater contributed by soil leachate showed that this contaminant would not travel far enough to reach the groundwater within 200 years due to the extraordinary high value of organic carbon partition coefficient ($K_{oc} = 87096 \text{ cm}^3/\text{g}$) under any of the following four scenarios:

- **Scenario 1:** Continuous source release for 10 years with 0.5 in/yr of recharge
- **Scenario 2:** Continuous source release for 10 years with 1.0 in/yr of recharge
- **Scenario 3:** Continuous source release for 100 years with 0.5 in/yr of recharge

- **Scenario 4:** Continuous source release for 100 years with 1.0 in/yr of recharge

Even with the worst case scenario, i.e. continuous source release for 100 years with 1.0 in/yr of recharge, the mixing concentration in groundwater was still undetectable. Because of the incomplete pathway (bis[2-ethylhexyl]phthalate in soil does not impact groundwater) there is, therefore, no need to evaluate bis(2-ethylhexyl)phthalate concentration in soil protective of groundwater.

2.1.2 Soil Concentration Protective of Sediment and Surface Water

Even though bis(2-ethylhexyl)phthalate in the soil does not impact the groundwater, it could be carried away by erosion of sediment caused by a rainstorm and transported to a nearby stream – Goose Prairie Creek that is 120 feet away from the source on land surface.

2.1.2.1 Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Sediment

A screening calculation was performed to evaluate whether storm water from an affected property has the potential to pose a risk to human or ecological receptors in Goose Prairie Creek. First, soil loss from the affected property was evaluated by the revised universal soil loss equation (RUSLE) before soil concentration protective of sediment could be calculated. **Table 1** summarizes input parameters for calculations of soil concentrations protective of sediment and surface water using the RUSLE program.

Calculate ^{Sed}Soil PCL

The soil concentration protective of sediment, ^{Sed}Soil PCL (or C_{AP}), is calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT}) - (SL_{OA} \times C_{OA})}{SL_{AP}} \quad (\text{mg/kg}) \quad \text{Equation L1}$$

where:

- C_{AP} = the ^{Sed}Soil PCL (mg/kg) for the surface water runoff pathway from the affected area
- SL_{TOT} = total sediment load estimated for the entire contributing watershed. (0.86 tons/ac-yr = 860 kg/ac-yr, **Table 1**).
- C_{TOT} = COC sediment PCL (mg/kg)
- SL_{OA} = sediment load (kg/yr) estimated for other areas of the watershed
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds. Because there is no Texas-specific median background soil concentrations, $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area
- SL_{AP} = sediment load from the affected property (kg/yr). In this case = 0.68 ton/ac-yr = 680 kg/ac-yr.

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT})}{SL_{AP}} \quad \text{Equation L2}$$

where:

$SL_{TOT} = 860 \text{ kg/ac-yr}$

$SL_{AP} = 680 \text{ kg/ac-yr}$

$C_{TOT} = 240 \text{ mg/kg}$ (sediment PCL for bis(2-ethylhexyl)phthalate for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002)

Therefore, $C_{AP} (\text{SedSoil MSC}) = (860)(240)/680 = 303.5 \text{ mg/kg}$.

Note that bis(2-ethylhexyl)phthalate concentration in soil at the source that can be eroded is 200 mg/kg which is smaller than SedSoil MSC of 303.5 mg/kg.

2.1.2.2 *Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Surface Water (SWSoil MSC)*

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation L3}$$

where:

C_{AP} = concentration of bis(2-ethylhexyl)phthalate in runoff from the affected property (mg/L)

Q_D = flow downstream of the affected property watershed (feet^3/sec), using 7Q2 flow

C_D = concentration of bis(2-ethylhexyl)phthalate downstream of the affected property (mg/L)

Q_{AP} = runoff from the affected property (feet^3/sec)

Q_{OA} = runoff from other areas of the affected property watershed (feet^3/sec)

C_{OA} = concentration of bis(2-ethylhexyl)phthalate in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U) \quad \text{Equation L4}$$

where:

R_{VU} = runoff coefficient (unitless) for land use type U ($\text{inches}_{\text{run}}/\text{inches}_{\text{rain}}$)

I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated using the following equation:

$$Q = P \times P_J \times R_{VU} \times A_U \text{ (in feet}^3\text{/sec)} \quad \text{Equation L5}$$

where:

- P = precipitation rate (inches/year)
- P_J = ratio of storms producing runoff (unit less) with a default value of 0.9
- R_{VU} = runoff coefficient (unit less) for land use type U (inches_{run}/inches_{rain})
- A_U = area of land use type u (acres)

At LHAAP-35A(58), the affected property was estimated to be 4.1 acres. The annual precipitation at LHAAP was estimated to be 45 inches/year read from the “Water Atlas of the United States” (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 60 % and 40 %, respectively. Therefore, for the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.6)](4.1)\} = 9.2 \text{ feet}^3\text{/sec}$$

Since C_{OA} = 0, the term Q_{OA} × C_{OA} = 0 and therefore the other areas of the affected property watershed are omitted.

Q_D = 2.5 ft³/sec (Based on 7Q2 flow, actually the 10th percentile flow was used (**Figure 1** and **Table 3**) based on the TCEQ requirement (2003) when the flow record is less than 5 years)

The solute concentration of bis(2-ethylhexyl)phthalate in soil, *Conc_{soil}* (mg/kg), can be calculated based on the soil concentration of 200,000 µg/kg using the equation as follows (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation L6}$$

where:

- ρ_b = bulk density of soil = assumed 1.7 g/cm³
- k_d = distribution coefficient = 87.1 cm³/g (**Table 1**)
- φ_w = water-filled porosity = 0.35
- φ_a = air-filled porosity = assumed 0.15
- H_c = Henry’s law coefficient = assumed 0.024 (dimensionless)

$$Conc_{source} = \frac{200.0 \times 1.7}{(87.1 \times 1.7 + 0.35 + 0.024 \times 0.15)} = 2.29 \text{ mg/L} = C_{AP}$$

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (9.2)(2.29)/2.5 = 8.43 \text{ mg/L} = 8,430 \text{ } \mu\text{g/L}$$

This concentration ($C_D = 8,430 \text{ } \mu\text{g/L}$) is much greater than the TCEQ MSC of $6 \text{ } \mu\text{g/L}$ for bis(2-ethylhexy)phthalate in surface water.

When bis(2-ethylhexy)phthalate concentration downstream of the affected property (C_D) is set equal to the maximum contaminant level (MCL) or the MSC of $6 \text{ } \mu\text{g/L}$, the resulting CAP represents the risk-based bis(2-ethylhexy)phthalate concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (2.5)(6)/(9.2) = 1.63 \text{ } \mu\text{g/L}$$

Using the equation utilized to convert soil concentration into solution concentration or vice versa, bis(2-ethylhexy)phthalate concentration in soil (C_{soil}) can be derived by:

$$C_{\text{soil}} = \frac{[k_d \times \rho_d + \phi_w + H\phi_a]C_{AP}}{\rho_b} = [(87.1 \times 1.7) + 0.35 + 0.024(0.15)](1.63)/1.7$$

$$= 142.3 \text{ } \mu\text{g/kg}$$

This value C_{soil} ($=^{\text{SW}}$ Soil MSC), i.e., soil concentration protective of surface water is much smaller than the actual bis(2-ethylhexy)phthalate concentration of $200,000 \text{ } \mu\text{g/kg}$ at the source.

2.1.3 Summary and Conclusion

Calculation result shows that the current concentration of bis(2-ethylhexy)phthalate in the soil is protective of sediment but not protective of surface water in Goose Prairie Creek. This is due to the fact that the calculated concentration in the water at the downstream end of the affected property is higher than the MSC of $6.0 \text{ } \mu\text{g/L}$ for bis(2-ethylhexyl)phthalate.

2.2 LHAAP-46

Bis(2-ethylhexyl)phthalate in the subsurface soil, together with the contaminated soil particles will be transported by storm-generated runoff to a nearby surface water body – Goose Prairie Creek – Middle; approximately 875 feet down slope of LHAAP-46. This distance is the shortest distance to the creek on land surface and, therefore, it is different from the distance used in Appendix G where the distance referenced to the creek is the distance within groundwater.

2.2.1 Leachate Modeling

Based on the leachate modeling for LHAAP-35A(58), a concentration of $690 \text{ } \mu\text{g/kg}$ in the soil at LHAAP-46 will not cause detectable levels of bis(2-ethylhexyl)phthalate in the groundwater.

2.2.2 Soil Concentrations Protective of Sediment and Surface Water

Even though bis(2-ethylhexyl)phthalate in the soil does not impact the groundwater, it could be carried away by erosion of sediment caused by a rainstorm and transported to a nearby stream – Goose Prairie Creek.

2.2.2.1 Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Sediment (^{sed}Soil MSC)

Given the close proximity of LHAAP-35A(58) and LHAAP-46, it is assumed that the physical and geographic conditions are similar at the two sites. Since the same chemical bis(2-ethylhexyl)phthalate is detected at both sites, the calculated soil concentration protective of sediment (^{sed}Soil MSC) at LHAAP-35A(58) is used at LHAAP-46. The current soil bis(2-ethylhexyl)phthalate concentration of 690 µg/kg at LHAAP-46, is lower than the calculated ^{sed}Soil MSC of 303,500 µg/kg. In addition, the distance to the water body is even longer at LHAAP-46 than at LHAAP-35A(58) by 375 feet. Therefore, it is not necessary to re-calculate the sediment PCL at LHAAP-46.

2.2.2.2 Bis(2-ethylhexyl)phthalate Concentration in Erodable Soil Protective of Surface Water (^{SW}Soil MSC)

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation L7}$$

where:

- C_{AP} = concentration of bis(2-ethylhexyl)phthalate in runoff from the affected property (mg/L)
- Q_D = flow downstream of the affected property watershed (feet³/sec), using 7Q2 flow (the 10th percentile was used based on TCEQ requirement [2003]).
- C_D = concentration of bis(2-ethylhexyl)phthalate downstream of the affected property (mg/L)
- Q_{AP} = runoff from the affected property (feet³/sec)
- Q_{OA} = runoff from other areas of the affected property watershed (feet³/sec)
- C_{OA} = concentration of bis(2-ethylhexyl)phthalate in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U) \quad \text{Equation L8}$$

where:

R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
 I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated using the following equation:

$$Q = P \times P_J \times R_{VU} \times A_U \text{ (in feet}^3\text{/sec)} \quad \text{Equation L9}$$

where:

P = precipitation rate (inches/year)
 P_J = ratio of storms producing runoff (unit less) with a default value of 0.9
 R_{VU} = runoff coefficient (unit less) for land use type U (inches_{run}/inches_{rain})
 A_U = area of land use type u (acres)

At LHAAP-46, the affected property was approximated to be 0.1469 acres (80 feet x 80 feet – a more realistic but still conservative estimation). The annual precipitation at LHAAP was estimated to be 45 inches/year read from the “Water Atlas of the United States” (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 50 % and 10 %, respectively. Therefore,

For the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.6)](0.1469)\} = 0.33 \text{ ft}^3\text{/sec}$$

Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and therefore the other areas of the affected property watershed are omitted.

Since no flow and cross sectional data are available for Goose Prairie Creek – Middle, data of the nearby creek, Goose Prairie Creek, were used.

$$Q_D = 2.5 \text{ ft}^3\text{/sec (Based on 10}^{\text{th}}\text{ percentile flow for Goose Prairie Creek – see Figure 1 and Table 3)}$$

The solute concentration of bis(2-ethylhexyl)phthalate in soil, $Conc_{source}$ (in mg/l), can be derived from the soil concentration of 0.69 mg/kg, $Conc_{soil}$ (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{source} = \frac{Conc_{soil} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation L10}$$

where:

ρ_b = bulk density of soil = assumed 1.7 g /cm³
 k_d = distribution coefficient = 87.1 cm³/g
 ϕ_w = water-filled porosity = 0.35
 ϕ_a = air-filled porosity = assumed 0.15

H_c = Henry's law coefficient = assumed 0.024 (dimensionless)

$$Conc_{source} = \frac{0.69 \times 1.7}{(87.1 \times 1.7 + 0.35 + 0.024 \times 0.15)} = 0.033 \text{ mg/L}$$

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.33)(0.033)/2.5 = 0.0044 \text{ mg/L} = 4.4 \text{ } \mu\text{g/L}$$

This concentration ($C_D = 4.4 \text{ } \mu\text{g/L}$) is less than the TCEQ MSC of $6 \text{ } \mu\text{g/L}$ for bis(2-ethylhexyl)phthalate in surface water.

When bis(2-ethylhexyl)phthalate concentration downstream of the affected property (C_D) is set equal to the MCL or MSC of $6 \text{ } \mu\text{g/L}$, the resulting CAP represents the risk-based bis(2-ethylhexyl)phthalate concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (2.5)(6)/(0.33) = 45.5 \text{ } \mu\text{g/L} \quad \text{Equation L11}$$

Using the equation above, bis(2-ethylhexyl)phthalate concentration in soil (C_{soil}) can be derived by:

$$C_{soil} = \frac{[k_d \rho_b + \phi_w + H \phi_a] C_{AP}}{\rho_b} = [87.1 \times 1.7 + 0.35 + 0.024(0.15)](45.5)/1.7$$

$$= 3,973 \text{ } \mu\text{g/kg}$$

This value C_{soil} ($=^{SW}$ Soil MSC), i.e. soil concentration protective of surface water is much greater than the actual bis(2-ethylhexyl)phthalate concentration of $690 \text{ } \mu\text{g/kg}$ at the source.

2.2.3 Results

Bis(2-ethylhexyl)phthalate in surface soil at a concentration of $690 \text{ } \mu\text{g/kg}$ is protective of sediment and surface water.

2.3 LHAAP-48

Elevated vinyl chloride and tetrachloroethane were detected in surface soil at sampling location LHS9901 at concentrations of 497 and $204 \text{ } \mu\text{g/kg}$, respectively. Due to elevated concentrations of these chemicals in soil, the vertical downward transport and horizontal pathway transported by eroded soil were modeled to evaluate the COCs contribution to groundwater and possibly, surface water and sediment.

2.3.1 Leachate Modeling

A VLEACHSM model was employed to obtain the leachate mixing concentration hydrographs of vinyl chloride (VC) and tetrachloroethene (PCE) in the groundwater at LHAAP-48.

2.3.1.1 Assumptions and Input Parameters

Because of the uncertainty of the input parameters, conservative values were used and assumptions were made as described below:

- **Contaminant Source:** No continuous source, instantaneous source is assumed. Vinyl chloride and perchlorate are found in top soil. Maximum concentrations of vinyl chloride and tetrachloroethane in surface soil were detected at 497 and 204 µg/kg at sampling location LHS9901, respectively
- Chemical properties of each chemical including the carbon partition coefficient, water-soil distribution coefficient, and half-life are listed in **Table 2**.
- **Longitudinal dispersivity:** 0.54 feet for calculation of vertical movement of COCs and mixing in groundwater.
- **Vertical dispersivity:** 0.05 feet for COCs vertical migration
- Average hydraulic conductivity (K) based on the slug tests at LHAAP-48 was estimated to be 3.8×10^{-5} cm/sec (Jacobs, 2002a)
- **Hydraulic gradient:** 0.00679 feet/feet based on the groundwater level map (9/00-Jacobs 2001b)
- **Recharge rate:** Assumed 1 inch per year in the vadose zone.

2.3.1.2 Simulation Results

Simulation results indicated that the mixing concentrations of vinyl chloride and tetrachloroethene in groundwater are 4.8 and 0.3 µg/L, respectively (**Figures 2 and 3**). Though vinyl chloride concentration is slightly higher than its MCL, the mixing concentration in the tributary will be way below the MCL of 2 µg/L.

2.3.2 Soil Concentration Protective of Sediment and Surface Water

Vinyl chloride and tetrachloroethene in the subsurface soil, with concentration of 497 and 204 µg/kg, respectively, together with the contaminated soil particles will be transported by storm-generated runoff to a nearby surface water bodies – in this case the tributary of Central Creek. The shortest distance from the source to this tributary is approximately 100 feet.

Given the similar physical and geographical condition of LHAAP-35C(53) and other sites, the sediment yield generated by soil erosion at LHAAP-48 would be similar. Because of the

relatively low concentration of vinyl chloride and tetrachloroethene, it is anticipated that these two chemicals would be protective of sediment and surface water.

2.3.2.1 Vinyl Chloride and Tetrachloroethene Concentrations in Erovable Soil Protective of Sediment

A screening calculation was performed to evaluate whether storm water from an affected property has the potential to pose a risk to human or ecological receptors in the Central Creek. First, soil loss from the affected property was evaluated by the RUSLE program before soil concentration protective of sediment could be calculated. **Table 1** summarizes input parameters and results for calculations of soil concentrations protective of sediment and surface water.

Calculation of ^{Sed}Soil MSC:

The soil concentration protective of sediment, ^{Sed}Soil MSC (or C_{AP}), is calculated using the following equation:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT}) - (SL_{OA} \times C_{OA})}{SL_{AP}} \quad (\text{in mg/kg}) \quad \text{Equation L12}$$

where:

- C_{AP} = the ^{Sed}Soil MSC (mg/kg) for the surface water runoff pathway from the affected area
- SL_{TOT} = total sediment load estimated for the entire contributing watershed. (0.38 tons/ac-yr = 380 kg/ac-yr, **Table 1**).
- C_{TOT} = COC sediment PCL (mg/kg)
- SL_{OA} = sediment load (kg/yr) estimated for other areas of the watershed
- C_{OA} = background soil concentration for inorganic COCs (if available). This term is zero for organic compounds. Because there is no Texas-specific median background soil concentrations, $C_{OA} = 0$.
- OA = other area. This is the area of contributing watershed other than the affected area
- SL_{AP} = sediment load from the affected property (in kg/yr). In this case, 0.34 tons/ac-yr = 340 kg/ac-yr.

The above equation can be simplified as:

$$C_{AP} = \frac{(SL_{TOT} \times C_{TOT})}{SL_{AP}} \quad \text{Equation L13}$$

where:

- SL_{TOT} = 380 kg/ac-yr
- SL_{AP} = 340 kg/ac-yr
- C_{TOT} = 36 and 1000 mg/kg (sediment PCL for vinyl chloride and tetrachloroethane, respectively for human risk, Table for Risk Reduction Program Rule, TNRCC, 2002)

Therefore, $C_{AP}(\text{SedSoil MSC}) = (380)(36)/340 = 38 \text{ mg/kg}$ (vinyl chloride)

$$C_{AP}(\text{SedSoil MSC}) = (380)(1000)/340 = 1117.6 \text{ mg/kg}$$
 (tetrachloroethane)

Note that vinyl chloride and tetrachloroethene concentrations in soil at the source that can be eroded are 0.497 and 0.204 mg/kg, which are much lower than SedSoil MSC of 1117.6 and 38 mg/kg, respectively.

2.3.2.2 Vinyl Chloride and Tetrachloroethene Concentrations in Erovable Soil Protective of Surface Water

The equation used to estimate the COC concentration in runoff from the affected property is as follows:

$$C_{AP} = \frac{Q_D \times C_D - Q_{OA} C_{OA}}{Q_{AP}} \quad \text{Equation L14}$$

where:

- C_{AP} = concentration of chemicals in runoff from the affected property (mg/L)
- Q_D = flow downstream of the affected property watershed (feet³/sec), using 7Q2 flow
- C_D = concentration of chemicals downstream of the affected property (mg/L)
- Q_{AP} = runoff from the affected property (feet³/sec)
- Q_{OA} = runoff from other areas of the affected property watershed (feet³/sec)
- C_{OA} = concentration of chemicals in runoff from other areas of the affected property watershed (mg/L) ($C_{OA} = 0$ in this case)

The calculation of runoff rates and volumes was based on the Schueler Method (Schueler, 1987):

First, the runoff coefficient for each land use type was derived with the following equation:

$$R_{VU} = 0.05 + (0.009 \times I_U) \quad \text{Equation L15}$$

where:

- R_{VU} = runoff coefficient (unitless) for land use type U (inches_{run}/inches_{rain})
- I_U = percent imperviousness (unitless) characteristic of land use type U

The runoff flow rates were then calculated using the following equation:

$$Q = P \times P_J \times R_{VU} \times A_U \text{ (in feet}^3\text{/sec)} \quad \text{Equation L16}$$

where:

- P = precipitation rate (inches/year)
- P_J = ratio of storms producing runoff (unit less) with a default value of 0.9

R_{VU} = runoff coefficient (unit less) for land use type U ($\text{inches}_{\text{run}}/\text{inches}_{\text{rain}}$)
 A_U = area of land use type u (acres)

At LHAAP-48, the affected property was assumed to be 0.0143 acres (25 feet \times 25 feet). The annual precipitation at LHAAP was estimated to be 45 inches/year according to the “Water Atlas of the United States” (Miller and Troise, 1973). The percent imperviousness (I_U) for the affected property area and the other areas of the affected property watershed are 30 percent and 10 percent, respectively. Therefore,

For the affected property area:

$$Q_{AP} = \{(45)(0.9)[0.05 + (0.009 \times 0.3)](0.0143)\} = 0.0305 \text{ feet}^3/\text{sec}$$

Since $C_{OA} = 0$, the term $Q_{OA} \times C_{OA} = 0$ and therefore the other areas of the affected property watershed are omitted.

$Q_D = 1.75 \text{ ft}^3/\text{sec}$ (Based on 7Q2 flow, estimated with the 10th percentile flow [Figure 4 and Table 4])

The solute concentration of vinyl chloride and tetrachloroethane in soil, $Conc_{\text{source}}$ (in mg/l), can be derived from the soil concentration of 0.497 mg/kg (vinyl chloride), and 0.204 mg/kg (tetrachloroethene), $Conc_{\text{soil}}$ (Feenstra, et al., 1991; USEPA, 2001):

$$Conc_{\text{source}} = \frac{Conc_{\text{soil}} \times \rho_b}{(k_d \rho_b + \phi_w + H_c \phi_a)} \quad \text{Equation L17}$$

where:

ρ_b = bulk density of soil = assumed 1.7 g/cm³
 k_d = distribution coefficient = Assumed 0.0 cm³/g
 ϕ_w = water-filled porosity = 0.35
 ϕ_a = air-filled porosity = assumed 0.15
 H_c = Henry's law coefficient (see Table 2)

$$Conc_{\text{source}} = \frac{0.497 \times 1.7}{(0.011 \times 1.7 + 0.35 + 1.11 \times 0.15)} = 1.58 \text{ mg/L (vinyl chloride)}$$

$$Conc_{\text{source}} = \frac{0.204 \times 1.7}{(0.155 \times 1.7 + 0.35 + 0.754 \times 0.15)} = 0.477 \text{ mg/L (tetrachloroethene)}$$

Therefore, for the resultant concentration downstream of the affected property C_D is:

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.0305)(1.58)/1.75 = 0.0275 \text{ mg/L} = 27.5 \text{ } \mu\text{g/L} \quad (\text{vinyl chloride})$$

$$C_D = \frac{Q_{AP} C_{AP}}{Q_D} = (0.0305)(0.477)/1.75 = 0.0083 \text{ mg/L} = 8.3 \text{ } \mu\text{g/L} \quad (\text{tetrachloroethane})$$

The concentrations of vinyl chloride ($C_D = 27.5 \text{ } \mu\text{g/L}$) and tetrachloroethene ($C_D = 8.3 \text{ } \mu\text{g/L}$) are greater than their MCLs of $2 \text{ } \mu\text{g/L}$ and $5 \text{ } \mu\text{g/L}$, respectively. The calculated values can be reduced to below the MCL if the affected area can be further reduced to 10 feet \times 10 feet.

When vinyl chloride concentration downstream of the affected property (C_D) is compared to the ^{SW}RBEL or the surface water PCL (^{SW}SW), it can be regarded as MCL of $2 \text{ } \mu\text{g/L}$ (vinyl chloride), the resulting CAP represents the risk-based vinyl chloride concentration protective of the receiving surface water. Therefore,

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (1.75)(2)/(0.0305) = 114.8 \text{ } \mu\text{g/L} \quad (\text{vinyl chloride})$$

$$C_{AP} = \frac{Q_D C_D}{Q_{AP}} = (1.75)(5)/(0.0305) = 286.9 \text{ } \mu\text{g/L} \quad (\text{PCE})$$

Using the equation used above, vinyl chloride concentration in soil (C_{soil}) can be derived:

$$C_{\text{soil}} = \frac{[k_d \times \rho_b + \phi_w + H\phi_a] C_{AP}}{\rho_b} = [0.011 \times 1.7 + 0.35 + 1.11(0.15)](114.8)/1.7$$

$$= 36.1 \text{ } \mu\text{g/kg} \quad (\text{vinyl chloride})$$

$$C_{\text{soil}} = \frac{[k_d \times \rho_b + \phi_w + H\phi_a] C_{AP}}{\rho_b} = [0.011 \times 1.7 + 0.35 + 1.11(0.15)](286.9)/1.7$$

$$= 122.6 \text{ } \mu\text{g/kg} \quad (\text{PCE})$$

These values, $C_{\text{soil}} = {}^{\text{SW}}\text{Soil MSC}$, i.e., soil concentration protective of surface water are smaller than the actual vinyl chloride concentration of $497 \text{ } \mu\text{g/kg}$ and tetrachloroethene concentration of $204 \text{ } \mu\text{g/kg}$ at the source.

2.3.3 Results

Vinyl chloride and tetrachloroethene in soil, though elevated in concentration, will not adversely impact surface water when the COCs migrate vertically to groundwater because their mixing concentrations in groundwater are already below their respective MCLs. However, when the soil

they adhered to is eroded and transported to surface water, their concentrations are not protective of surface water.

3.0 References

References are provided in the main document, Section 8.0.

Table 1
Input Parameters and Results for Additional Calculations
of Soil Concentrations Protective of Sediment and Surface Water

Site No.	LHAAP-35A(58)	LHAAP-48
Parameter/Units		
Distance to nearest stream (feet)	120	100
Topographic slope (%)	0.4	1.5
Topsoil (%)	29% - silt 70% - clay 1% - organic matter	30% - silt 60% - clay 1% - organic matter
Soil erodibility (K) (ton/ac per unit of R)		
Affected area	0.19	0.12
Total area	0.19	0.12
Length and Steepness Factors		
Affected area	0.08	0.2
Total area	0.085	0.23
Cover Management Factor (C)		
Affected area	0.16	0.12
Total area	0.14	0.12
Overall Slope Gradient (%)		
Affected area	0.1	1.5
Total area	0.69	1.5
Support Practice Factor (P)		
Affected area	0.82	0.58
Total area	0.98	0.58
Soil Loss - A (tons/ac-yr)		
Affected area	0.74	0.66
Total area	0.92	0.74
Annual Sediment Yield (tons/ac-yr)		
Affected area	0.68	0.34
Total area	0.86	0.38
Sediment Delivery Ratio		
Affected area	0.74	0.3
Total area	0.92	0.3
		PCE - 1117.6 VC - 38
^{Sed} Soil PCL (mg/kg) (C _{AP})	303.5	
^{SW} Soil PCL (mg/kg) (C _{soil})	1.475	VC - 0.0256
		PCE - 0.497 VC - 0.204
Maximum Source Concentration (mg/kg)	200	
Maximum Soil Concentration > C _{soil}	No	No
Maximum Soil Concentration > C _{AP}	No	No

Table 2
Input Parameters for Additional Modeling of Soil Concentrations Protective of Groundwater

Site No.	LHAAP-35A(58)	LHAAP-48	
Parameter/Units			
Distance to nearest stream (feet)	120	100	
Depth to groundwater (feet)	12	10	
Source Area in soil (feet x feet)	600 x 500	25 x 25	
Hydraulic conductivity (cm/sec)	6.36×10^{-4}	3.8×10^{-5}	
Hydraulic gradient	0.0072	0.00679	
Longitudinal dispersivity (feet)	0.458	0.54	
Vertical dispersivity (feet)	0.153	0.05	
Source concentration ($\mu\text{g/kg}$)	200,000	497	204
Chemical Parameters	Bis(ethylhexyl)phthalate	Vinyl Chloride	Tetrachlorethane
Organic carbon partition coefficient (cm^3/g)	87096	11	155
Distribution coefficient (K_d) (cm^3/g)	87	0.011	0.155
Henry's law constant (dimensionless)	4.18E-06	1.11E+00	0.754
Free air diffusion coefficient (cm^2/sec)	0.0351	0.106	0.072
Aqueous solubility ($\mu\text{g/L}$)	350	1,100,000	2,200,000
Half-life (year)	Not considered	8	2

Table 3
Calculation of Flow Discharge in Goose Prairie Creek
(Data Collected from December 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth (feet)		Measured Velocity (feet/second)		Cross Sectional Area (feet ²)		Calculated Discharge (cfs)		Average Discharge (cfs)
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
Dec-99	3 - 9	0.10830	0.22081	1.44906	4.88410	2.80	4.20	4.0574	20.5132	12.2853
	10 - 16	0.11651	0.30483	0.48774	2.94988	3.21	6.87	1.5656	20.2657	10.916
	17 - 23	0.06315	0.37523	0.45438	2.12994	2.10	8.56	0.9542	18.2323	9.593
	24 - 30	0.06315	0.36534	0.45438	14.99560	2.10	7.88	0.9542	118.1653	59.560
Jan-00	1 - 7	0.02700	0.36224	0.21000	7.10767	1.05	7.98	0.2205	56.7192	28.470
	8 - 14	0.12681	0.44958	0.24389	11.82963	3.45	18.63	0.8414	220.3860	110.614
	15 - 21	0.03749	0.36559	0.03032	11.51831	1.41	8.35	0.0428	96.1779	48.110
	22 - 28	0.06279	0.42399	0.80813	14.08148	2.08	17.56	1.6809	247.2708	124.476
Feb-00	1 - 7	0.09417	0.42572	0.12182	9.59478	2.65	20.51	0.3228	196.7889	98.556
	8 - 14	0.05132	0.37422	0.04973	6.47123	1.75	8.01	0.0870	51.8346	25.961
	15 - 21	0.03763	0.37675	0.04530	0.53829	1.48	9.24	0.0670	4.9738	2.520
Mar-00	22 - 28	0.14625	0.48311	0.35183	1.14280	4.45	20.51	1.5656	23.4388	12.502
	1 - 7	0.10288	0.37274	0.16989	0.50621	2.79	7.95	0.4740	4.0244	2.249
	8 - 14	0.20995	0.58798	0.48053	1.13559	6.10	21.55	2.9312	24.4720	13.702

Notes and Abbreviations:

Measured depths and measured velocities are averaged values over every seven days.

Average flow discharges are the average values of upstream and downstream discharges.

cfs cubic feet per second

Table 4
Calculation of Flow Discharge in the Central Creek (Downstream)
(Data Collected from Dec 1, 1999 to March 15, 2000)

Month-Year	Day of Month	Measured Depth	Measured Velocity	Cross Sectional Area	Calculated Discharge
		(ft)	(ft/s)	(ft ²)	(cfs)
		Downstream	Downstream	Downstream	Downstream
Dec-99	3 - 9	1.11074	1.29100	6.31	8.1462
	10 - 16	1.48660	0.25542	7.30	1.8646
	17 - 23	1.46344	0.73705	7.25	5.3436
	24 - 30	1.32520	0.23729	7.00	1.6610
Jan-00	1 - 7	1.06090	0.29642	11.90	3.5274
	8 - 14	1.62076	0.19877	10.80	2.1467
	15 - 21	1.48365	0.15027	7.20	1.0819
	22 - 28	1.36087	3.31644	11.00	36.4808
Feb-00	1 - 7	1.63820	0.54047	6.12	3.3077
	8 - 14	1.51571	0.25153	11.70	2.9429
	15 - 21	1.44892	1.64454	7.26	11.9394
	22 - 28	1.55024	0.25240	7.15	1.8047
Mar-00	1 - 7	2.07625	3.62250	17.90	64.8428
	8 - 14	2.40898	2.59353	25.30	65.6163

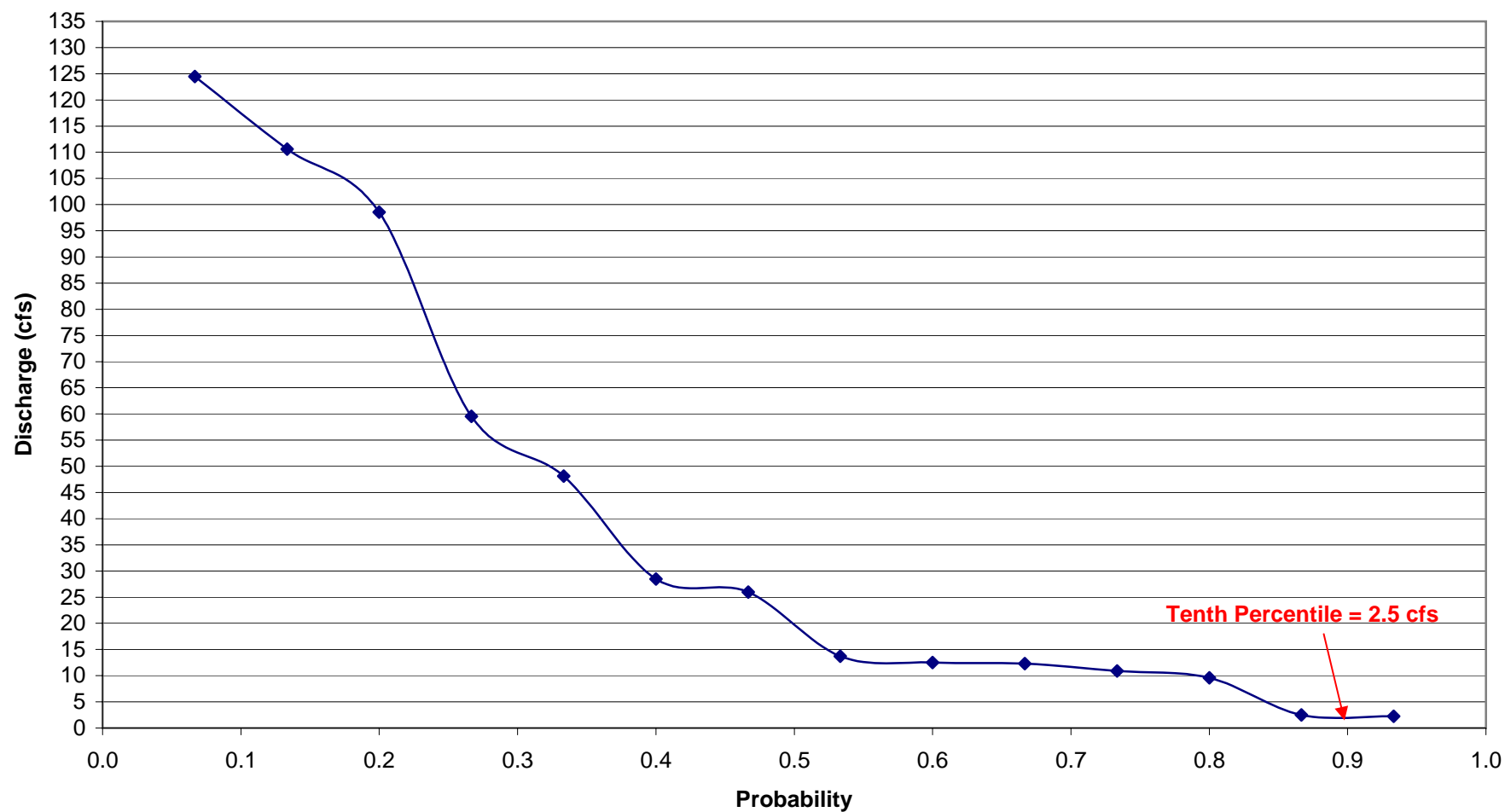
Notes:

Measured depths and measured velocities are averaged values over every seven days

Cross sectional areas are based on the measured depths and cross sections

cfs = cubic feet per second

Figure 1 - Appendix L
Low Flow Analysis
Probability vs Flow Discharge for Goose Prairie Creek
Based on December 1999 to March 2000 Flow Derivation



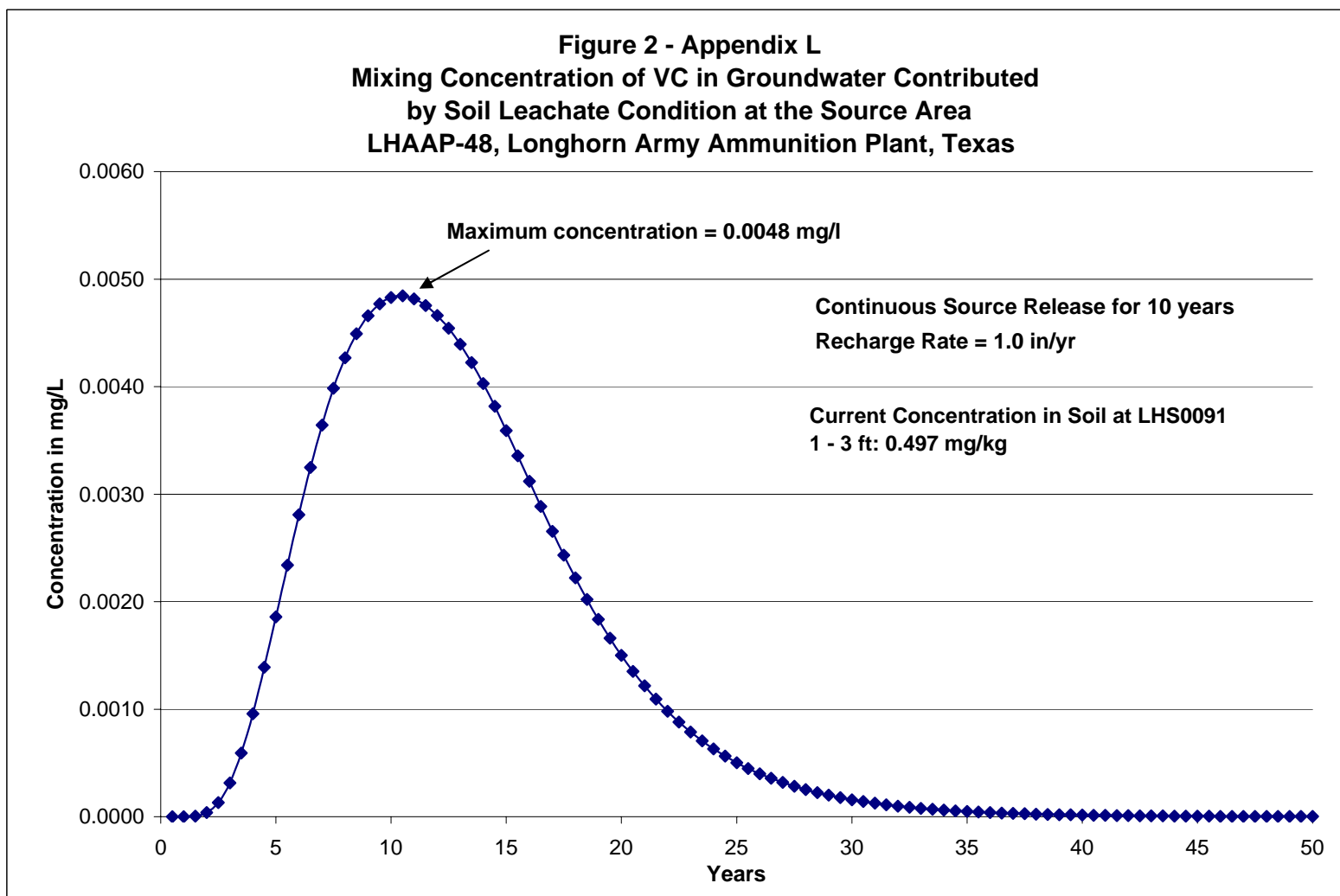


Figure 3 - Appendix L
Mixing Concentration of PCE in Groundwater Contributed
by Soil Leachate Condition at the Source Area
LHAAP-48, Longhorn Army Ammunition Plant, Texas

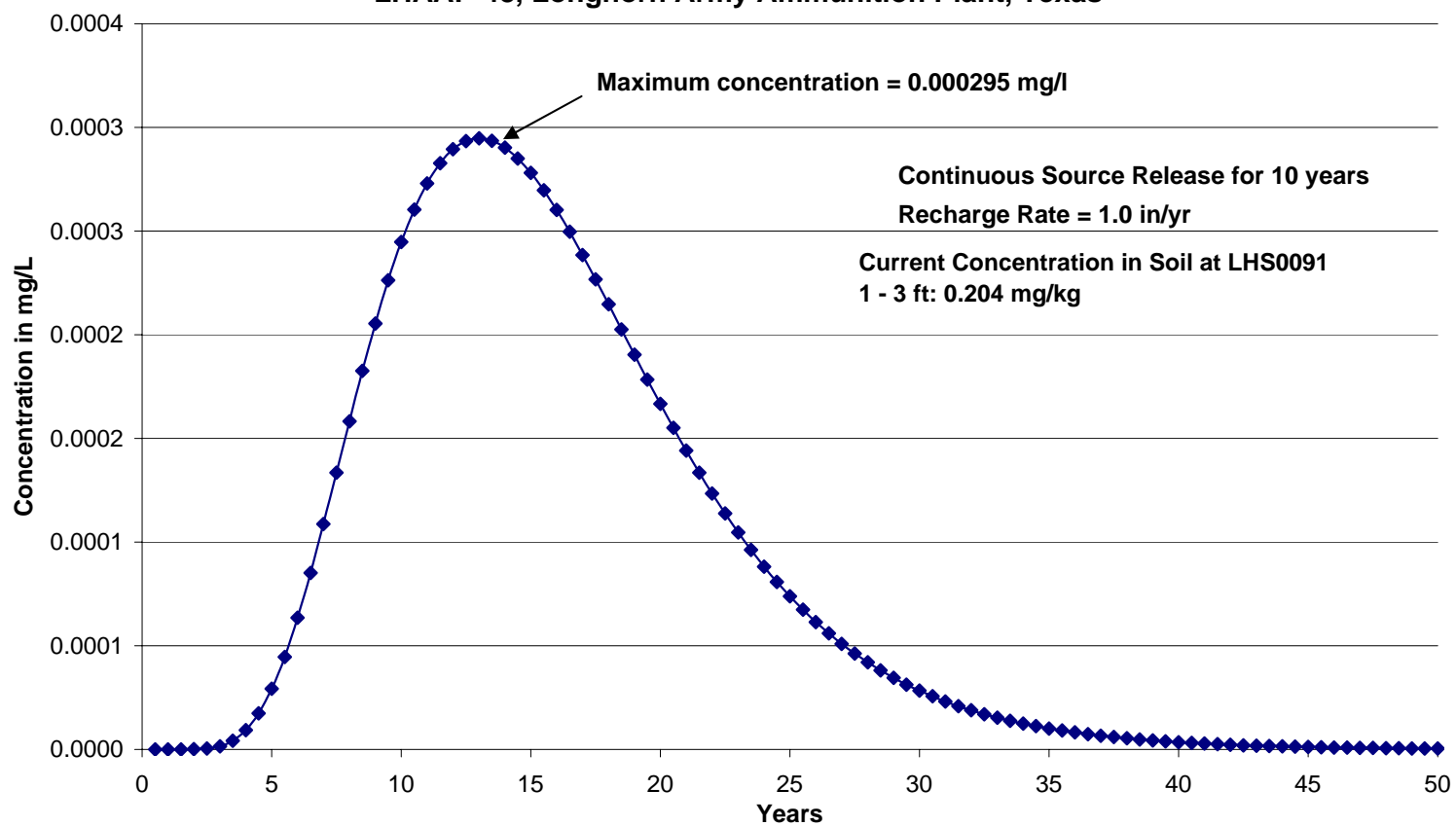
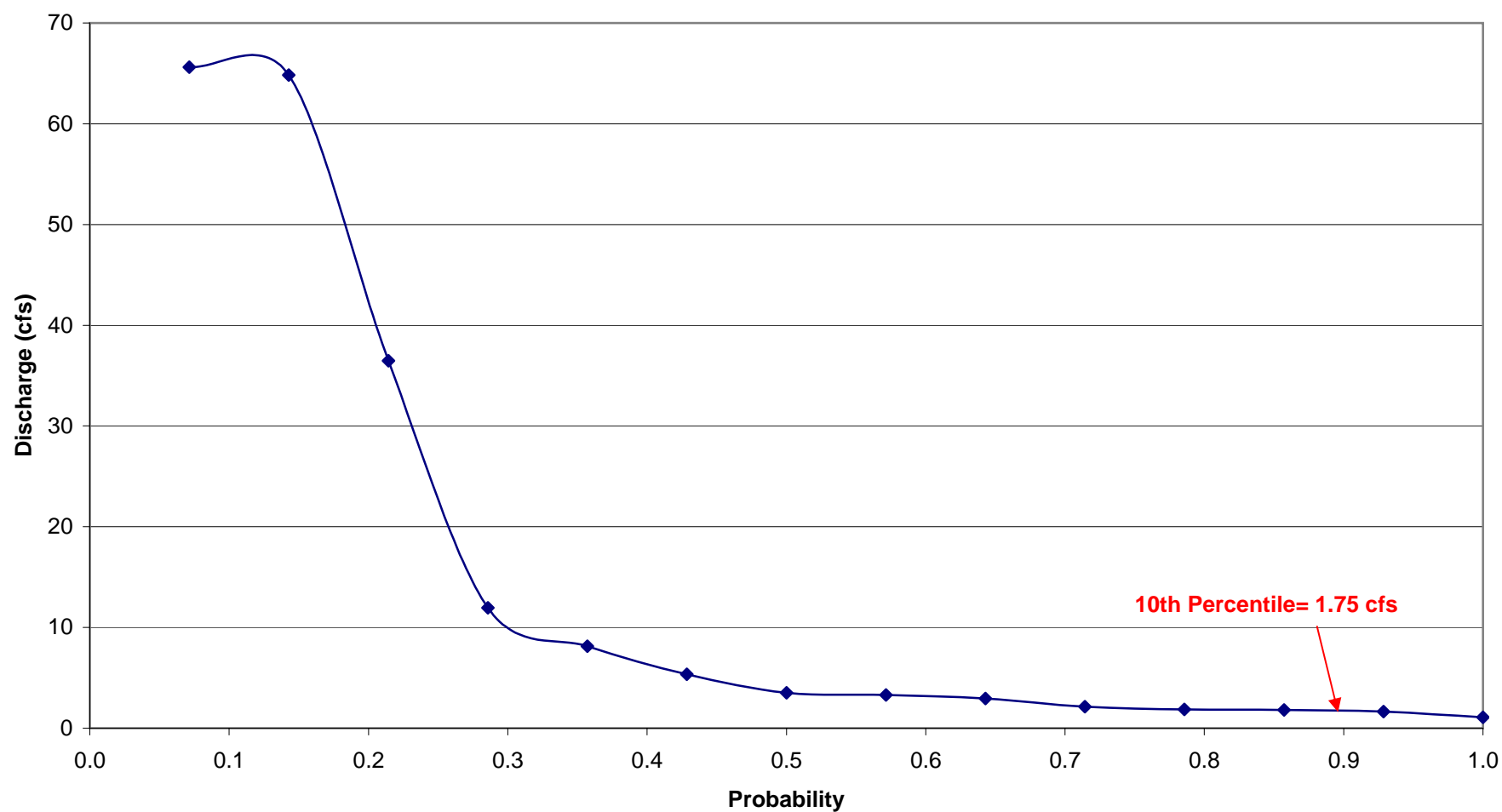


Figure 4 - Appendix L
Low Flow Analysis
Probability vs Flow Discharge for Central Creek (Downstream)
Based on December 1999 to March 2000 Flow Derivation



Attachment A

***Computer Printout for the Mixing Concentration of
Bis(2-ethylhexyl)phthalate in Groundwater Caused by Leachate from
Soil at LHAAP-35A(58)***

**SATURATED GW CONCENTRATION (underneath columns) DUE TO' MIXING
SOIL COLUMNS ARE ARRANGED 90 DEGREE TO GROUND-WATER DIRECTION
Liquid Phase Concentrations [mg/L]**

Soil Column 1	[mg/L]		
TIME	Cin(vadose)	Cin(aquifer)	Cout(mixed)
0.50	0.00000E+00	0.00000E+00	0.00000E+00
1.00	0.00000E+00	0.00000E+00	0.00000E+00
1.50	0.00000E+00	0.00000E+00	0.00000E+00
2.00	0.00000E+00	0.00000E+00	0.00000E+00
2.50	0.00000E+00	0.00000E+00	0.00000E+00
3.00	0.00000E+00	0.00000E+00	0.00000E+00
3.50	0.00000E+00	0.00000E+00	0.00000E+00
4.00	0.00000E+00	0.00000E+00	0.00000E+00
4.50	0.00000E+00	0.00000E+00	0.00000E+00
5.00	0.00000E+00	0.00000E+00	0.00000E+00
5.50	0.00000E+00	0.00000E+00	0.00000E+00
6.00	0.00000E+00	0.00000E+00	0.00000E+00
6.50	0.00000E+00	0.00000E+00	0.00000E+00
7.00	0.00000E+00	0.00000E+00	0.00000E+00
7.50	0.00000E+00	0.00000E+00	0.00000E+00
8.00	0.00000E+00	0.00000E+00	0.00000E+00
8.50	0.00000E+00	0.00000E+00	0.00000E+00
9.00	0.00000E+00	0.00000E+00	0.00000E+00
9.50	0.00000E+00	0.00000E+00	0.00000E+00
10.00	0.00000E+00	0.00000E+00	0.00000E+00
10.50	0.00000E+00	0.00000E+00	0.00000E+00
11.00	0.00000E+00	0.00000E+00	0.00000E+00
11.50	0.00000E+00	0.00000E+00	0.00000E+00
12.00	0.00000E+00	0.00000E+00	0.00000E+00
12.50	0.00000E+00	0.00000E+00	0.00000E+00
13.00	0.00000E+00	0.00000E+00	0.00000E+00
13.50	0.00000E+00	0.00000E+00	0.00000E+00
14.00	0.00000E+00	0.00000E+00	0.00000E+00
14.50	0.00000E+00	0.00000E+00	0.00000E+00
15.00	0.00000E+00	0.00000E+00	0.00000E+00
15.50	0.00000E+00	0.00000E+00	0.00000E+00
16.00	0.00000E+00	0.00000E+00	0.00000E+00
16.50	0.00000E+00	0.00000E+00	0.00000E+00
17.00	0.00000E+00	0.00000E+00	0.00000E+00
17.50	0.00000E+00	0.00000E+00	0.00000E+00
18.00	0.00000E+00	0.00000E+00	0.00000E+00
18.50	0.00000E+00	0.00000E+00	0.00000E+00
19.00	0.00000E+00	0.00000E+00	0.00000E+00
19.50	0.00000E+00	0.00000E+00	0.00000E+00
20.00	0.00000E+00	0.00000E+00	0.00000E+00
20.50	0.00000E+00	0.00000E+00	0.00000E+00
21.00	0.00000E+00	0.00000E+00	0.00000E+00
21.50	0.00000E+00	0.00000E+00	0.00000E+00
22.00	0.00000E+00	0.00000E+00	0.00000E+00
22.50	0.00000E+00	0.00000E+00	0.00000E+00
23.00	0.00000E+00	0.00000E+00	0.00000E+00
23.50	0.00000E+00	0.00000E+00	0.00000E+00
24.00	0.00000E+00	0.00000E+00	0.00000E+00
24.50	0.00000E+00	0.00000E+00	0.00000E+00
25.00	0.00000E+00	0.00000E+00	0.00000E+00
25.50	0.00000E+00	0.00000E+00	0.00000E+00
26.00	0.00000E+00	0.00000E+00	0.00000E+00

26.50	0.00000E+00	0.00000E+00	0.00000E+00
27.00	0.00000E+00	0.00000E+00	0.00000E+00
27.50	0.00000E+00	0.00000E+00	0.00000E+00
28.00	0.54370E-42	0.00000E+00	0.00000E+00
28.50	0.15344E-41	0.00000E+00	0.00000E+00
29.00	0.25237E-41	0.00000E+00	0.00000E+00
29.50	0.35131E-41	0.00000E+00	0.49045E-43
30.00	0.45038E-41	0.00000E+00	0.49045E-43
30.50	0.54931E-41	0.00000E+00	0.49045E-43
31.00	0.64824E-41	0.00000E+00	0.49045E-43
31.50	0.74731E-41	0.00000E+00	0.49045E-43
32.00	0.88086E-41	0.00000E+00	0.99492E-43
32.50	0.10789E-40	0.00000E+00	0.99492E-43
33.00	0.12767E-40	0.00000E+00	0.99492E-43
33.50	0.14747E-40	0.00000E+00	0.14854E-42
34.00	0.16874E-40	0.00000E+00	0.14854E-42
34.50	0.19844E-40	0.00000E+00	0.19758E-42
35.00	0.22813E-40	0.00000E+00	0.19758E-42
35.50	0.26031E-40	0.00000E+00	0.24803E-42
36.00	0.29989E-40	0.00000E+00	0.24803E-42
36.50	0.33948E-40	0.00000E+00	0.29708E-42
37.00	0.38847E-40	0.00000E+00	0.34612E-42
37.50	0.43943E-40	0.00000E+00	0.39657E-42
38.00	0.49882E-40	0.00000E+00	0.44561E-42
38.50	0.56364E-40	0.00000E+00	0.49466E-42
39.00	0.63441E-40	0.00000E+00	0.54370E-42
39.50	0.71360E-40	0.00000E+00	0.64320E-42
40.00	0.80217E-40	0.00000E+00	0.69224E-42
40.50	0.89966E-40	0.00000E+00	0.79173E-42
41.00	0.10070E-39	0.00000E+00	0.89123E-42
41.50	0.11248E-39	0.00000E+00	0.98932E-42
42.00	0.12560E-39	0.00000E+00	0.10888E-41
42.50	0.13990E-39	0.00000E+00	0.12373E-41
43.00	0.15564E-39	0.00000E+00	0.13859E-41
43.50	0.17290E-39	0.00000E+00	0.15344E-41
44.00	0.19181E-39	0.00000E+00	0.16830E-41
44.50	0.21259E-39	0.00000E+00	0.18805E-41
45.00	0.23536E-39	0.00000E+00	0.20781E-41
45.50	0.26020E-39	0.00000E+00	0.22757E-41
46.00	0.28727E-39	0.00000E+00	0.25237E-41
46.50	0.31686E-39	0.00000E+00	0.27718E-41
47.00	0.34908E-39	0.00000E+00	0.30688E-41
47.50	0.38416E-39	0.00000E+00	0.33645E-41
48.00	0.42242E-39	0.00000E+00	0.37120E-41
48.50	0.46398E-39	0.00000E+00	0.40582E-41
49.00	0.50897E-39	0.00000E+00	0.44533E-41
49.50	0.55786E-39	0.00000E+00	0.48989E-41
50.00	0.61086E-39	0.00000E+00	0.53446E-41
50.50	0.66826E-39	0.00000E+00	0.58883E-41
51.00	0.73037E-39	0.00000E+00	0.64334E-41
51.50	0.79747E-39	0.00000E+00	0.70275E-41
52.00	0.87007E-39	0.00000E+00	0.76203E-41
52.50	0.94846E-39	0.00000E+00	0.83139E-41
53.00	0.10330E-38	0.00000E+00	0.90566E-41
53.50	0.11243E-38	0.00000E+00	0.98974E-41
54.00	0.12227E-38	0.00000E+00	0.10738E-40
54.50	0.13286E-38	0.00000E+00	0.11678E-40
55.00	0.14426E-38	0.00000E+00	0.12669E-40
55.50	0.15652E-38	0.00000E+00	0.13757E-40

56.00	0.16968E-38	0.00000E+00	0.14896E-40
56.50	0.18383E-38	0.00000E+00	0.16133E-40
57.00	0.19902E-38	0.00000E+00	0.17469E-40
57.50	0.21531E-38	0.00000E+00	0.18904E-40
58.00	0.23277E-38	0.00000E+00	0.20438E-40
58.50	0.25148E-38	0.00000E+00	0.22070E-40
59.00	0.27152E-38	0.00000E+00	0.23853E-40
59.50	0.29297E-38	0.00000E+00	0.25733E-40
60.00	0.31591E-38	0.00000E+00	0.27763E-40
60.50	0.34043E-38	0.00000E+00	0.29890E-40
61.00	0.36662E-38	0.00000E+00	0.32216E-40
61.50	0.39458E-38	0.00000E+00	0.34640E-40
62.00	0.42443E-38	0.00000E+00	0.37263E-40
62.50	0.45627E-38	0.00000E+00	0.40084E-40
63.00	0.49022E-38	0.00000E+00	0.43053E-40
63.50	0.52639E-38	0.00000E+00	0.46220E-40
64.00	0.56492E-38	0.00000E+00	0.49635E-40
64.50	0.60593E-38	0.00000E+00	0.53197E-40
65.00	0.64955E-38	0.00000E+00	0.57058E-40
65.50	0.69595E-38	0.00000E+00	0.61116E-40
66.00	0.74526E-38	0.00000E+00	0.65470E-40
66.50	0.79766E-38	0.00000E+00	0.70073E-40
67.00	0.85332E-38	0.00000E+00	0.74922E-40
67.50	0.91240E-38	0.00000E+00	0.80118E-40
68.00	0.97508E-38	0.00000E+00	0.85661E-40
68.50	0.10416E-37	0.00000E+00	0.91501E-40
69.00	0.11121E-37	0.00000E+00	0.97686E-40
69.50	0.11868E-37	0.00000E+00	0.10422E-39
70.00	0.12659E-37	0.00000E+00	0.11120E-39
70.50	0.13497E-37	0.00000E+00	0.11852E-39
71.00	0.14383E-37	0.00000E+00	0.12634E-39
71.50	0.15321E-37	0.00000E+00	0.13455E-39
72.00	0.16313E-37	0.00000E+00	0.14326E-39
72.50	0.17362E-37	0.00000E+00	0.15247E-39
73.00	0.18470E-37	0.00000E+00	0.16222E-39
73.50	0.19641E-37	0.00000E+00	0.17251E-39
74.00	0.20877E-37	0.00000E+00	0.18335E-39
74.50	0.22181E-37	0.00000E+00	0.19483E-39
75.00	0.23558E-37	0.00000E+00	0.20690E-39
75.50	0.25010E-37	0.00000E+00	0.21967E-39
76.00	0.26541E-37	0.00000E+00	0.23313E-39
76.50	0.28155E-37	0.00000E+00	0.24728E-39
77.00	0.29855E-37	0.00000E+00	0.26223E-39
77.50	0.31646E-37	0.00000E+00	0.27796E-39
78.00	0.33532E-37	0.00000E+00	0.29449E-39
78.50	0.35518E-37	0.00000E+00	0.31196E-39
79.00	0.37607E-37	0.00000E+00	0.33032E-39
79.50	0.39805E-37	0.00000E+00	0.34962E-39
80.00	0.42116E-37	0.00000E+00	0.36991E-39
80.50	0.44545E-37	0.00000E+00	0.39124E-39
81.00	0.47099E-37	0.00000E+00	0.41366E-39
81.50	0.49782E-37	0.00000E+00	0.43721E-39
82.00	0.52599E-37	0.00000E+00	0.46195E-39
82.50	0.55558E-37	0.00000E+00	0.48799E-39
83.00	0.58664E-37	0.00000E+00	0.51525E-39
83.50	0.61922E-37	0.00000E+00	0.54386E-39
84.00	0.65341E-37	0.00000E+00	0.57389E-39
84.50	0.68927E-37	0.00000E+00	0.60537E-39
85.00	0.72687E-37	0.00000E+00	0.63842E-39

85.50	0.76628E-37	0.00000E+00	0.67301E-39
86.00	0.80757E-37	0.00000E+00	0.70929E-39
86.50	0.85083E-37	0.00000E+00	0.74729E-39
87.00	0.89615E-37	0.00000E+00	0.78708E-39
87.50	0.94359E-37	0.00000E+00	0.82875E-39
88.00	0.99325E-37	0.00000E+00	0.87235E-39
88.50	0.10452E-36	0.00000E+00	0.91802E-39
89.00	0.10996E-36	0.00000E+00	0.96578E-39
89.50	0.11565E-36	0.00000E+00	0.10157E-38
90.00	0.12160E-36	0.00000E+00	0.10680E-38
90.50	0.12781E-36	0.00000E+00	0.11225E-38
91.00	0.13431E-36	0.00000E+00	0.11797E-38
91.50	0.14110E-36	0.00000E+00	0.12393E-38
92.00	0.14820E-36	0.00000E+00	0.13016E-38
92.50	0.15561E-36	0.00000E+00	0.13667E-38
93.00	0.16335E-36	0.00000E+00	0.14347E-38
93.50	0.17142E-36	0.00000E+00	0.15056E-38
94.00	0.17985E-36	0.00000E+00	0.15797E-38
94.50	0.18865E-36	0.00000E+00	0.16569E-38
95.00	0.19783E-36	0.00000E+00	0.17375E-38
95.50	0.20740E-36	0.00000E+00	0.18216E-38
96.00	0.21739E-36	0.00000E+00	0.19093E-38
96.50	0.22779E-36	0.00000E+00	0.20007E-38
97.00	0.23864E-36	0.00000E+00	0.20959E-38
97.50	0.24994E-36	0.00000E+00	0.21953E-38
98.00	0.26172E-36	0.00000E+00	0.22987E-38
98.50	0.27399E-36	0.00000E+00	0.24065E-38
99.00	0.28677E-36	0.00000E+00	0.25187E-38
99.50	0.30007E-36	0.00000E+00	0.26355E-38
100.00	0.31392E-36	0.00000E+00	0.27572E-38
100.50	0.32834E-36	0.00000E+00	0.28838E-38
101.00	0.34334E-36	0.00000E+00	0.30156E-38
101.50	0.35895E-36	0.00000E+00	0.31526E-38
102.00	0.37518E-36	0.00000E+00	0.32952E-38
102.50	0.39207E-36	0.00000E+00	0.34435E-38
103.00	0.40963E-36	0.00000E+00	0.35977E-38
103.50	0.42788E-36	0.00000E+00	0.37580E-38
104.00	0.44685E-36	0.00000E+00	0.39247E-38
104.50	0.46657E-36	0.00000E+00	0.40978E-38
105.00	0.48705E-36	0.00000E+00	0.42778E-38
105.50	0.50833E-36	0.00000E+00	0.44647E-38
106.00	0.53044E-36	0.00000E+00	0.46588E-38
106.50	0.55339E-36	0.00000E+00	0.48604E-38
107.00	0.57722E-36	0.00000E+00	0.50697E-38
107.50	0.60196E-36	0.00000E+00	0.52870E-38
108.00	0.62764E-36	0.00000E+00	0.55125E-38
108.50	0.65429E-36	0.00000E+00	0.57466E-38
109.00	0.68194E-36	0.00000E+00	0.59894E-38
109.50	0.71062E-36	0.00000E+00	0.62413E-38
110.00	0.74037E-36	0.00000E+00	0.65027E-38
110.50	0.77122E-36	0.00000E+00	0.67736E-38
111.00	0.80321E-36	0.00000E+00	0.70546E-38
111.50	0.83638E-36	0.00000E+00	0.73459E-38
112.00	0.87076E-36	0.00000E+00	0.76478E-38
112.50	0.90638E-36	0.00000E+00	0.79607E-38
113.00	0.94330E-36	0.00000E+00	0.82849E-38
113.50	0.98154E-36	0.00000E+00	0.86208E-38
114.00	0.10212E-35	0.00000E+00	0.89688E-38
114.50	0.10622E-35	0.00000E+00	0.93292E-38

115.00	0.11047E-35	0.00000E+00	0.97025E-38
115.50	0.11487E-35	0.00000E+00	0.10089E-37
116.00	0.11942E-35	0.00000E+00	0.10489E-37
116.50	0.12414E-35	0.00000E+00	0.10903E-37
117.00	0.12902E-35	0.00000E+00	0.11332E-37
117.50	0.13407E-35	0.00000E+00	0.11775E-37
118.00	0.13929E-35	0.00000E+00	0.12234E-37
118.50	0.14470E-35	0.00000E+00	0.12709E-37
119.00	0.15029E-35	0.00000E+00	0.13200E-37
119.50	0.15607E-35	0.00000E+00	0.13707E-37
120.00	0.16205E-35	0.00000E+00	0.14232E-37
120.50	0.16823E-35	0.00000E+00	0.14775E-37
121.00	0.17462E-35	0.00000E+00	0.15336E-37
121.50	0.18122E-35	0.00000E+00	0.15916E-37
122.00	0.18805E-35	0.00000E+00	0.16516E-37
122.50	0.19510E-35	0.00000E+00	0.17135E-37
123.00	0.20238E-35	0.00000E+00	0.17775E-37
123.50	0.20991E-35	0.00000E+00	0.18437E-37
124.00	0.21769E-35	0.00000E+00	0.19119E-37
124.50	0.22572E-35	0.00000E+00	0.19825E-37
125.00	0.23401E-35	0.00000E+00	0.20553E-37
125.50	0.24258E-35	0.00000E+00	0.21305E-37
126.00	0.25142E-35	0.00000E+00	0.22082E-37
126.50	0.26054E-35	0.00000E+00	0.22883E-37
127.00	0.26996E-35	0.00000E+00	0.23711E-37
127.50	0.27968E-35	0.00000E+00	0.24564E-37
128.00	0.28971E-35	0.00000E+00	0.25445E-37
128.50	0.30006E-35	0.00000E+00	0.26354E-37
129.00	0.31074E-35	0.00000E+00	0.27292E-37
129.50	0.32175E-35	0.00000E+00	0.28259E-37
130.00	0.33311E-35	0.00000E+00	0.29257E-37
130.50	0.34482E-35	0.00000E+00	0.30285E-37
131.00	0.35690E-35	0.00000E+00	0.31346E-37
131.50	0.36935E-35	0.00000E+00	0.32440E-37
132.00	0.38219E-35	0.00000E+00	0.33567E-37
132.50	0.39542E-35	0.00000E+00	0.34730E-37
133.00	0.40906E-35	0.00000E+00	0.35927E-37
133.50	0.42311E-35	0.00000E+00	0.37162E-37
134.00	0.43760E-35	0.00000E+00	0.38434E-37
134.50	0.45252E-35	0.00000E+00	0.39744E-37
135.00	0.46789E-35	0.00000E+00	0.41094E-37
135.50	0.48372E-35	0.00000E+00	0.42485E-37
136.00	0.50003E-35	0.00000E+00	0.43918E-37
136.50	0.51683E-35	0.00000E+00	0.45393E-37
137.00	0.53412E-35	0.00000E+00	0.46912E-37
137.50	0.55193E-35	0.00000E+00	0.48476E-37
138.00	0.57027E-35	0.00000E+00	0.50086E-37
138.50	0.58914E-35	0.00000E+00	0.51744E-37
139.00	0.60857E-35	0.00000E+00	0.53450E-37
139.50	0.62856E-35	0.00000E+00	0.55206E-37
140.00	0.64914E-35	0.00000E+00	0.57013E-37
140.50	0.67031E-35	0.00000E+00	0.58873E-37
141.00	0.69209E-35	0.00000E+00	0.60786E-37
141.50	0.71451E-35	0.00000E+00	0.62755E-37
142.00	0.73756E-35	0.00000E+00	0.64779E-37
142.50	0.76127E-35	0.00000E+00	0.66862E-37
143.00	0.78566E-35	0.00000E+00	0.69004E-37
143.50	0.81074E-35	0.00000E+00	0.71207E-37
144.00	0.83653E-35	0.00000E+00	0.73472E-37

144.50	0.86305E-35	0.00000E+00	0.75801E-37
145.00	0.89031E-35	0.00000E+00	0.78195E-37
145.50	0.91833E-35	0.00000E+00	0.80657E-37
146.00	0.94714E-35	0.00000E+00	0.83187E-37
146.50	0.97674E-35	0.00000E+00	0.85787E-37
147.00	0.10072E-34	0.00000E+00	0.88459E-37
147.50	0.10384E-34	0.00000E+00	0.91205E-37
148.00	0.10706E-34	0.00000E+00	0.94027E-37
148.50	0.11036E-34	0.00000E+00	0.96926E-37
149.00	0.11375E-34	0.00000E+00	0.99904E-37
149.50	0.11723E-34	0.00000E+00	0.10296E-36
150.00	0.12081E-34	0.00000E+00	0.10610E-36
150.50	0.12448E-34	0.00000E+00	0.10933E-36
151.00	0.12826E-34	0.00000E+00	0.11265E-36
151.50	0.13213E-34	0.00000E+00	0.11605E-36
152.00	0.13611E-34	0.00000E+00	0.11954E-36
152.50	0.14019E-34	0.00000E+00	0.12313E-36
153.00	0.14439E-34	0.00000E+00	0.12681E-36
153.50	0.14869E-34	0.00000E+00	0.13059E-36
154.00	0.15311E-34	0.00000E+00	0.13447E-36
154.50	0.15764E-34	0.00000E+00	0.13846E-36
155.00	0.16229E-34	0.00000E+00	0.14254E-36
155.50	0.16707E-34	0.00000E+00	0.14674E-36
156.00	0.17197E-34	0.00000E+00	0.15104E-36
156.50	0.17700E-34	0.00000E+00	0.15545E-36
157.00	0.18215E-34	0.00000E+00	0.15998E-36
157.50	0.18744E-34	0.00000E+00	0.16463E-36
158.00	0.19287E-34	0.00000E+00	0.16939E-36
158.50	0.19843E-34	0.00000E+00	0.17428E-36
159.00	0.20414E-34	0.00000E+00	0.17930E-36
159.50	0.20999E-34	0.00000E+00	0.18444E-36
160.00	0.21599E-34	0.00000E+00	0.18971E-36
160.50	0.22215E-34	0.00000E+00	0.19511E-36
161.00	0.22846E-34	0.00000E+00	0.20065E-36
161.50	0.23493E-34	0.00000E+00	0.20633E-36
162.00	0.24156E-34	0.00000E+00	0.21216E-36
162.50	0.24835E-34	0.00000E+00	0.21813E-36
163.00	0.25532E-34	0.00000E+00	0.22424E-36
163.50	0.26245E-34	0.00000E+00	0.23051E-36
164.00	0.26977E-34	0.00000E+00	0.23694E-36
164.50	0.27727E-34	0.00000E+00	0.24352E-36
165.00	0.28495E-34	0.00000E+00	0.25027E-36
165.50	0.29282E-34	0.00000E+00	0.25718E-36
166.00	0.30088E-34	0.00000E+00	0.26426E-36
166.50	0.30914E-34	0.00000E+00	0.27151E-36
167.00	0.31760E-34	0.00000E+00	0.27894E-36
167.50	0.32626E-34	0.00000E+00	0.28655E-36
168.00	0.33513E-34	0.00000E+00	0.29435E-36
168.50	0.34422E-34	0.00000E+00	0.30233E-36
169.00	0.35353E-34	0.00000E+00	0.31050E-36
169.50	0.36306E-34	0.00000E+00	0.31887E-36
170.00	0.37282E-34	0.00000E+00	0.32744E-36
170.50	0.38280E-34	0.00000E+00	0.33621E-36
171.00	0.39303E-34	0.00000E+00	0.34520E-36
171.50	0.40350E-34	0.00000E+00	0.35439E-36
172.00	0.41422E-34	0.00000E+00	0.36380E-36
172.50	0.42518E-34	0.00000E+00	0.37344E-36
173.00	0.43641E-34	0.00000E+00	0.38330E-36
173.50	0.44790E-34	0.00000E+00	0.39339E-36

174.00	0.45966E-34	0.00000E+00	0.40371E-36
174.50	0.47169E-34	0.00000E+00	0.41428E-36
175.00	0.48399E-34	0.00000E+00	0.42509E-36
175.50	0.49659E-34	0.00000E+00	0.43615E-36
176.00	0.50947E-34	0.00000E+00	0.44747E-36
176.50	0.52265E-34	0.00000E+00	0.45904E-36
177.00	0.53614E-34	0.00000E+00	0.47088E-36
177.50	0.54993E-34	0.00000E+00	0.48300E-36
178.00	0.56403E-34	0.00000E+00	0.49539E-36
178.50	0.57846E-34	0.00000E+00	0.50806E-36
179.00	0.59321E-34	0.00000E+00	0.52102E-36
179.50	0.60830E-34	0.00000E+00	0.53427E-36
180.00	0.62373E-34	0.00000E+00	0.54782E-36
180.50	0.63950E-34	0.00000E+00	0.56167E-36
181.00	0.65563E-34	0.00000E+00	0.57584E-36
181.50	0.67212E-34	0.00000E+00	0.59032E-36
182.00	0.68897E-34	0.00000E+00	0.60512E-36
182.50	0.70620E-34	0.00000E+00	0.62025E-36
183.00	0.72382E-34	0.00000E+00	0.63572E-36
183.50	0.74182E-34	0.00000E+00	0.65153E-36
184.00	0.76022E-34	0.00000E+00	0.66769E-36
184.50	0.77902E-34	0.00000E+00	0.68421E-36
185.00	0.79824E-34	0.00000E+00	0.70109E-36
185.50	0.81787E-34	0.00000E+00	0.71833E-36
186.00	0.83794E-34	0.00000E+00	0.73596E-36
186.50	0.85844E-34	0.00000E+00	0.75396E-36
187.00	0.87938E-34	0.00000E+00	0.77236E-36
187.50	0.90078E-34	0.00000E+00	0.79115E-36
188.00	0.92264E-34	0.00000E+00	0.81035E-36
188.50	0.94497E-34	0.00000E+00	0.82996E-36
189.00	0.96778E-34	0.00000E+00	0.85000E-36
189.50	0.99108E-34	0.00000E+00	0.87046E-36
190.00	0.10149E-33	0.00000E+00	0.89136E-36
190.50	0.10392E-33	0.00000E+00	0.91270E-36
191.00	0.10640E-33	0.00000E+00	0.93450E-36
191.50	0.10893E-33	0.00000E+00	0.95676E-36
192.00	0.11152E-33	0.00000E+00	0.97949E-36
192.50	0.11416E-33	0.00000E+00	0.10027E-35
193.00	0.11686E-33	0.00000E+00	0.10264E-35
193.50	0.11962E-33	0.00000E+00	0.10506E-35
194.00	0.12243E-33	0.00000E+00	0.10753E-35
194.50	0.12530E-33	0.00000E+00	0.11005E-35
195.00	0.12823E-33	0.00000E+00	0.11262E-35
195.50	0.13122E-33	0.00000E+00	0.11525E-35
196.00	0.13427E-33	0.00000E+00	0.11793E-35
196.50	0.13739E-33	0.00000E+00	0.12067E-35
197.00	0.14057E-33	0.00000E+00	0.12346E-35
197.50	0.14381E-33	0.00000E+00	0.12631E-35
198.00	0.14713E-33	0.00000E+00	0.12922E-35
198.50	0.15050E-33	0.00000E+00	0.13219E-35
199.00	0.15395E-33	0.00000E+00	0.13522E-35
199.50	0.15747E-33	0.00000E+00	0.13831E-35
200.00	0.16106E-33	0.00000E+00	0.14146E-35

Appendix M

Creeks Survey and Water Elevation Data

Table of Contents

List of Tables	i
List of Figures	i
1.0 Introduction	1-1

List of Tables

Table 1	Comparison of Groundwater and Central Creek Surface Water Elevations – LHAAP-12
Table 2	Comparison of Groundwater and Goose Prairie Creek Surface Water Elevations LHAAP-35B(37)
Table 3	Comparison of Groundwater and Central Creek and Harrison Bayou Surface Water Elevations LHAAP-35C(53)
Table 4	Comparison of Groundwater and Goose Prairie Creek Surface Water Elevations LHAAP-46
Table 5	Comparison of Groundwater and Central Creek Surface Water Elevations LHAAP-48
Table 6	Survey Points for Saunders Branch

List of Figures

Figure 1	Creek Survey Location Map
Figure 2	Creek Survey

1.0 Introduction

Potential groundwater discharge into creeks was interpreted site by site using the creek survey data and groundwater elevation data from wells located within the vicinity of the creek. Groundwater elevation data from a single well alone was not the mitigating criteria for determining potential discharge, rather, consideration was given to the general groundwater flow direction at a site and by utilizing elevation data from all well groupings at that site.

Table 1
Comparison of Groundwater and Central Creek Surface Water Elevations - LHAAP-12

Well ID	TOC Elevation (feet)	Ground Elevation (feet)	Depth to Water Dry Sept. 2002 Wet March 2002 (feet)	Groundwater Elevations Dry Sept. 2002 Wet March 2002 (feet)	Surveyed Point in the Well Vicinity	Groundwater Discharge to the Creek
Dry Season Central Creek						
12WW01	204.19	201.61	22.4	181.79	CC2	No
12WW05	190.52	188.39	9.05	181.47	CC1	
12WW10	203.21	200.3	21.5	181.71	CC1	
12WW11	203.51	199.91	22.22	181.29	Deep	
12WW12	203.04	200.34	21.1	181.94	CC1	
12WW13	203.24	200.08	21.73	181.51	CC1	
12WW17	203.5	199.96	22	181.5	CC1	
12WW18	204.26	201.13	23.4	180.86	CC2	
Wet Season Central Creek						
12WW01	204.19	201.61	22.5	181.69	CC2	Potential discharge
12WW05	190.52	188.39	5.6	184.92	CC1	
12WW10	203.21	200.3	21.45	181.76	CC1	
12WW11	203.51	199.91	22.3	181.21	Deep	
12WW12	203.04	200.34	20	183.04	CC1	
12WW13	203.24	200.08	21.55	181.69	CC1	
12WW17	203.5	199.96	21	182.5	CC1	
12WW18	204.26	201.13	23.7	180.56	CC2	
Dry Season Harrison Bayou						
12WW01	204.19	201.61	22.4	181.79	HB	Yes
12WW05	190.52	188.39	9.05	181.47	HB	
12WW10	203.21	200.3	21.5	181.71	HB	
12WW11	203.51	199.91	22.22	181.29	Deep	
12WW12	203.04	200.34	21.1	181.94	HB	
12WW13	203.24	200.08	21.73	181.51	HB	
12WW17	203.5	199.96	22	181.5	HB	
12WW18	204.26	201.13	23.4	180.86	HB	
Wet Season Harrison Bayou						
12WW01	204.19	201.61	22.5	181.69	HB	Yes
12WW05	190.52	188.39	5.6	184.92	HB	
12WW10	203.21	200.3	21.45	181.76	HB	
12WW11	203.51	199.91	22.3	181.21	Deep	
12WW12	203.04	200.34	20	183.04	HB	
12WW13	203.24	200.08	21.55	181.69	HB	
12WW17	203.5	199.96	21	182.5	HB	
12WW18	204.26	201.13	23.7	180.56	HB	

Notes and Abbreviations:

Survey Point	CC1	CC1	CC2	CC2
Top of Creek Bank:	188.2	188.37	185.09	185.19
Bottom of Creek	182.01	181.9	183.41	182.92
Survey Point	CC3	CC3	HB	HB
Top of Creek Bank	171.99	171.91	167.85*	166.73*
Bottom of Creek	168.54	168.77		

* Not top of creek bank but edge of the swamp

TOC Top of Casing
CC Central Creek
HB Harrison Bayou

Table 2
Comparison of Groundwater and Goose Prairie Creek Surface Water Elevations
LHAAP-35B (37)

Well ID	TOC Elevation (feet)	Ground Elevation (feet)	Depth to Water Sept. 2004 (feet)	Groundwater Elevations Sept. 2004 (feet)	Surveyed Point in the Well Vicinity	Groundwater Discharge to the Creek
35BWW01	202.88	200.24	12.90	189.98	GPS	No
35BWW02	203.95	201.06	Dry	Dry	GPS	
35BWW03	203.56	201.34	21.68	181.88	GPS	
LHSMW58	203.56	200.20	17.25	186.31	GPS	
LHSMW59	204.18	201.07	17.89	186.29	GPS	

Notes and Abbreviations:

Survey Point	GPS	GPS
Top of Creek Bank	194.27	194.75
Bottom of Creek	187.21	187.50

TOC Top of Casing

GPS Goose Prairie Creek South

Table 3
Comparison of Groundwater and Central Creek and Harrison Bayou Surface Water Elevations
LHAAP-35C (53)

Well ID	TOC Elevation (feet)	Ground Elevation (feet)	Depth to Water Sept. 2004 (feet)	Groundwater Elevations Sept. 2004 (feet)	Surveyed Point in the Well Vicinity	Groundwater Discharge to Central Creek/ Harisson Bayou
106	179.05	175.65	12.82	166.23	CC3	No
107	178.32	175.73	10.22	168.10	HB	Yes
LHSMW67	185.57	182.64	17.11	168.46	HB	
LHSMW68	189.65	186.69	20.71	168.94	HB	
LHSMW69	183.27	180.16	15.22	168.05	HB	
LHSMW70	183.62	180.54	14.79	168.83	HB	
LHSMW71	183.73	181.00	16.23	167.50	HB	

Notes and Abbreviations:

Survey Point	CC3	CC3	HB	HB
Top of Creek Bank	171.99	171.91	167.85*	166.73*
Bottom of Creek	168.54	168.77		

TOC Top of Casing

CC Central Creek

HB Harrison Bayou

* Not top of creek bank but edge of the swamp

^a - Main channel center line of creek

Groundwater will not discharge to Central Creek but may potentially discharge to Harrison Bayou.

Table 4
Comparison of Groundwater and Goose Prairie Creek Surface Water Elevations
LHAAP-46

Well ID	TOC Elevation (feet)	Ground Elevation (feet)	Depth to Water Dry Sept. 2002 Wet March 2002 (feet)	Groundwater Elevations Dry Sept. 2002 Wet March 2002 (feet)	Surveyed Point in the Well Vicinity	Groundwater Discharge to the Creek
Dry Season						
46WW01	212.82	209.71	17.87	194.95	GPN2	Yes
46WW02	212.21	209.16	26.06	185.61	GPN2	
LHSMW19	212.96	209.74	16.31	196.65	GPN2	
LHSMW22	209.6	206.16	18.87	190.73	GPN2	
Wet Season						
46WW01	212.82	209.71	17	195.82	GPN2	Yes
46WW02	212.21	209.16	26.8	185.41	GPN2	
LHSMW19	212.96	209.74	16.6	196.36	GPN2	
LHSMW22	209.6	206.16	19.6	190	GPN2	

Notes and Abbreviations:

Survey Point	GPN2	GPN2
Top of Creek Bank	182.74	182.27
Bottom of Creek	179.94	180.06
TOC	Top of Casing	
GPN	Goose Prairie Creek North	

Table 5
Comparison of Groundwater and Central Creek Surface Water Elevations
LHAAP-48

Well ID	TOC Elevation (feet)	Ground Elevation (feet)	Depth to Water Sept. 2004 (feet)	Groundwater Elevations Sept. 2004 (feet)	Surveyed Point in the Well Vicinity	Groundwater Discharge to the Creek
48WW01	193.24	190.81	22.32	170.92	CC3	Yes
LHSMW62	192.20	189.06	20.91	171.29	CC3	
LHSMW63	194.06	191.01	21.60	172.46	CC3	
LHSMW64	191.42	188.23	21.33	170.09	CC3	
LHSMW65	194.31	191.80	19.93	174.38	CC3	
LHSMW66	195.11	192.23	19.97	175.14	CC3	

Notes and Abbreviations:

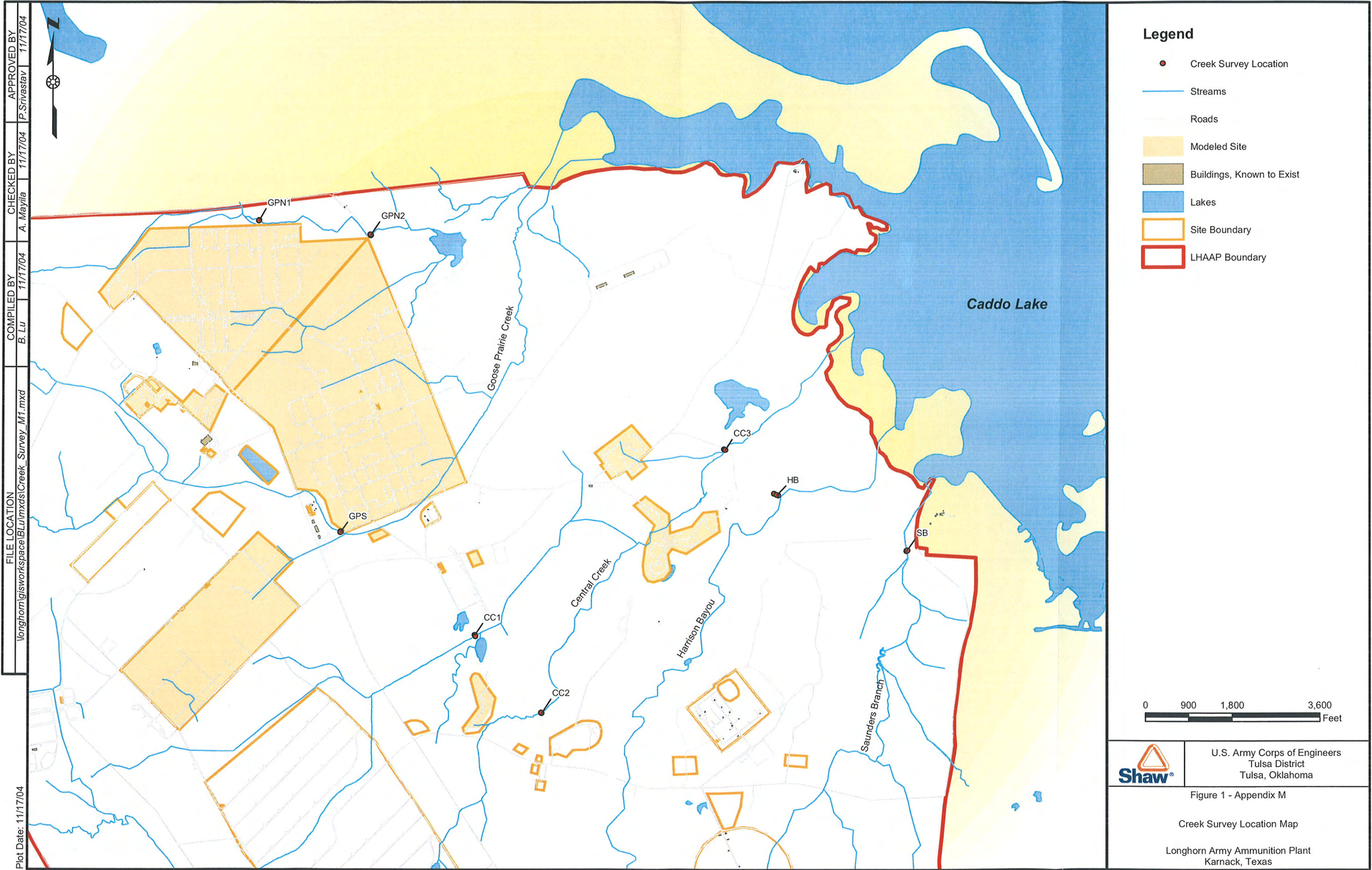
Survey Point	CC3	CC3
Top of Creek Bank	171.99	171.91
Bottom of Creek	168.54	168.77
TOC	Top of Casing	
CC	Central Creek	

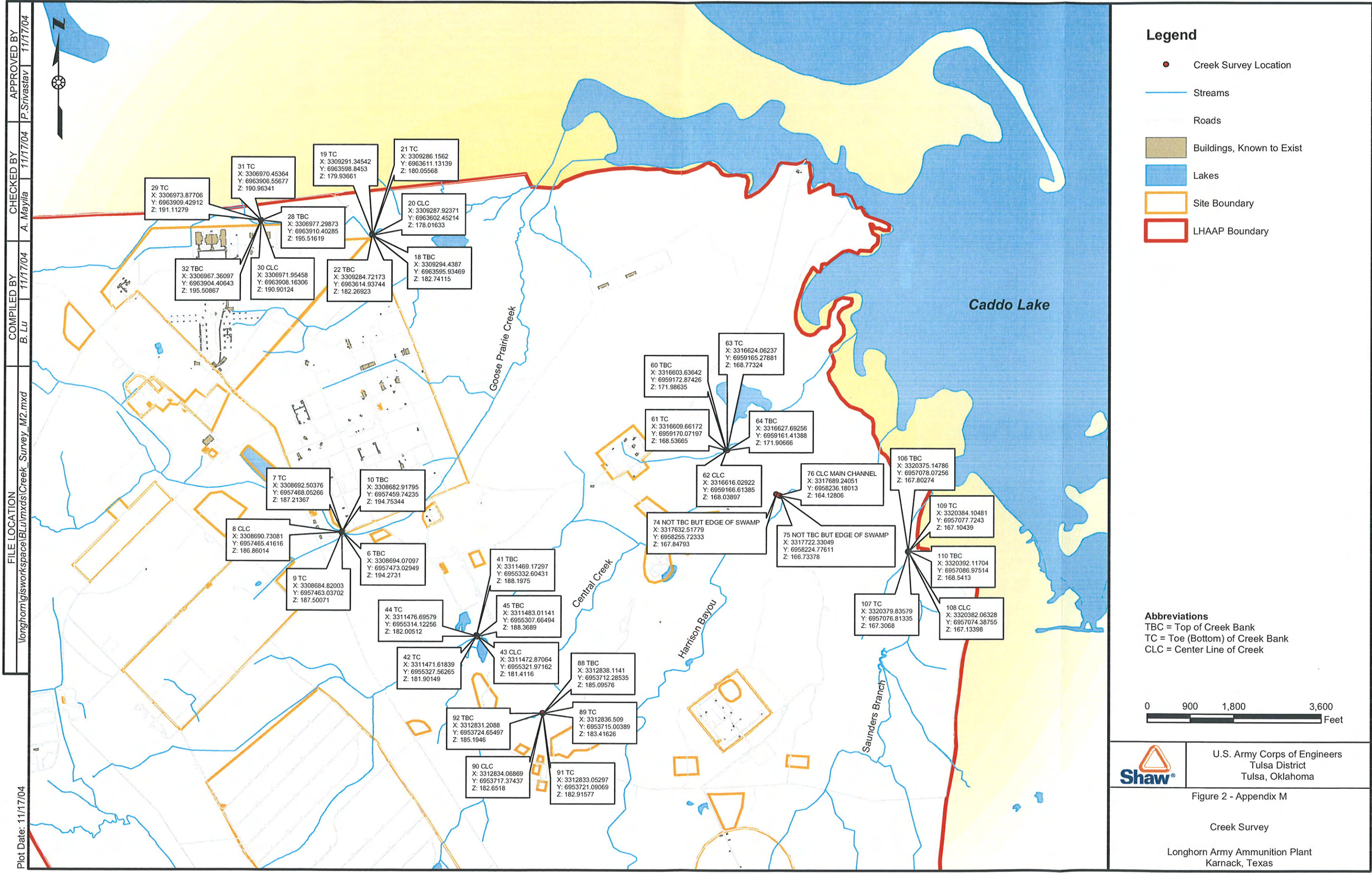
Table 6
Survey Points for Saunders Branch

Survey Point	SB	SB
Top of Creek Bank	167.80	168.54
Bottom of Creek	167.31	167.10

Abbreviation:

SB Saunders Branch







**Subject: Draft Final Minutes, Monthly Managers Meeting,
Longhorn Army Ammunition Plant (LHAAP)**

Location of Meeting: Teleconference

Date of Meeting: February 13, 2007, 1:00 PM – 3:30 PM

Meeting Participants:

BRAC:	Rose M. Zeiler
USACE-Tulsa:	Cliff Murray, Rick Smith, John Lambert
USAEC	Jeff Armstrong
Shaw Environmental:	Dave Cobb, Praveen Srivastav, John Elliott, Kay Everett, Van Vangala, Greg Jones
USEPA Region 6:	Chris Villarreal, Steve Tzhone, Scott Harris, Raji Josiam
TCEQ:	Fay Duke

Prior to the meeting Shaw and Army had distributed via e-mail: meeting agenda, minutes of January 24, 2007 Monthly Managers' Meeting, and the document status tables for the TERC and PBC projects.

Rose Zeiler opened the meeting and welcomed those in attendance. Rick Smith with the USACE-Tulsa District announced that John Lambert would be replacing him as the Longhorn project manager after a suitable transition period. John Lambert introduced himself to the group.

Shaw Action Items:

Shaw PBC

- **Inform Jeff Armstrong regarding expected end of February 2007 submittal date of BERA Vol. II so he can inform Larry Tannenbaum.** Dave Cobb said that comments are back on the Baseline Ecological Risk Assessment Volume II from the Army. They expect to submit Volume II in the last week of February or first week of March.
- **Set up a conference call with TCEQ and EPA to discuss GWTP sampling modification memo.** Dave indicated that a conference call had been conducted discussing the GWTP sampling memo.
- **Shaw to submit a memo presenting information to support the proposal to shut down extraction wells at LHAAP-16.** A memo has been submitted regarding the proposal to shutdown the extraction system at LHAAP-16.
- **Send an e-mail with proposed day and time for weekly or biweekly call with regulators.** Dave indicated that the weekly call program with the stakeholders has been

set up to help facilitate site work. The initial meeting walked through the modification sampling memo at LHAAP-18/24 and the memo requesting the shutdown of the system at LHAAP-16 for site sampling.

- **Provide a brief tech/design memo summarizing re-injection system at LHAAP-18/24 for Shaw's use in the field and for information to Army and regulators.** The design process has been started for the groundwater treatment plant's re-injection system/optimization.

Shaw TERC

- **Send response to comments on LHAAP- 37/67 Proposed Plan and Data Gaps Investigation Report to Raji Josiam (EPA) with copy to Chris Villarreal.** John Elliott informed the group that both documents were forwarded to the regulators on February 12, 2007
- **Send a revised table of MNA results, incorporating the Dec 2006 data, to EPA and TCEQ.** The revised table will be submitted on Thursday, February 15, 2007 and has been expanded to a technical memo with the table, data, and a figure.
- **Send revised risk evaluation for LHAAP-48/53 electronically to TCEQ with copy to EPA.** John Elliott informed the group that the report on LHAAP-48/53 would be submitted electronically on Thursday, February 15, 2007.
- **Shaw and Army to decide how to roll up MNA data and modeling for LHAAP-37 and 67 and inform regulators.** To be discussed.

USACE Action Item:

- **Cliff Murray to look up any documentation or background information that supported installation of extraction system at LHAAP-16. Also check with Jeff Armstrong to see if he has any information.** Cliff Murray briefly discussed the history of the LHAAP-16 extraction system pilot study. It originally was a 2-year pilot study from an Army document. An email explaining this history was issued. Fay Duke said she did not get the email. Chris Villarreal said some discussion was brought up during the 5-year review. The remedy for site 16 is the landfill cap so the extraction system itself was not the remedy.

TCEQ Action Items:

- **Dale Vodak/Fay Duke to find out requirements for IHW permit for the landfill at LHAAP-19.** Fay Duke indicated that what needs to be done regarding the construction landfill was completed.
- **Dale Vodak/Fay Duke to check on the permit requirements, if any, for dewatering of pits and use of a portable air stripping unit.** Still an item as Army will review relevant data to make a determination if a portable stripping unit is feasible to use in remediating the water from the pits.
- **Fay Duke to provide comments on perimeter well sampling frequency memo.** Completed.
- **Fay Duke to provide comments or concurrence for LHAAP-18/24 GWTP Sampling Modification Memo based on the outcome of the call (to be scheduled, see Shaw's action item)**

EPA Action Items:

- **Raji Josiam to confirm the availability of conference room for February 13, 2007 monthly managers' meeting in Dallas.** Completed, however, meeting was changed to teleconference.
- **Raji Josiam to check with Chris Villarreal regarding the status of ECOP IV review by EPA and inform Rose Zeiler.** Chris indicated that a letter is being drafted regarding ECOPIV. Rose said that she will revise the ECOPIV and send up to BRAC headquarters for signature. Chris indicated that he would wait until all revisions are incorporated in the document before getting the signatures needed.
- **Raji Josiam to check on the schedule for the EPA website on Longhorn.** Pending.
- **Chris Villarreal to call Susan Roddy and Marc Greenberg to make sure that the review of the BERA is on their schedule.** Done.

Steve Tzhone indicated that a new document will be available via the EPA website regarding MNA guidance and MNA determination. Vince Malott is the EPA's contact working on this document. This MNA guidance will be used to determine if MNA is working or not. There is some controversy on current guidance.

USGS and TVA are scheduled to conduct a flyover and an installation-wide water level event for March 18-24. USGW is waiting for the last download from Shaw. They are trying to determine how many wells are present, screening information, well surveys, well levels, etc. There are about 200-400 wells being looked at; however, water level data will not be collected from all wells, especially those in clusters. Some wells are just missing some information. Notification to Army and coordination with USFWS is necessary to enter the installation after March 14, the last day there will be security at the gate.

Defense Environmental Restoration Program (DERP) PBC Update (Dave Cobb/Praveen Srivastav)

Dave briefly hit the highlights on the document status table. He indicated that BERA Volume I document is being looked at by regulators. Dave said that Volume II will probably be available by the end of February to the regulators. Fay Duke indicated that comments were coming soon regarding the GWTP sampling optimization memo. The LHAAP-35/36 SI report is being prepared.

GWTP. Van Vangala provided an update on the GWTP operation. He indicated that the INF pond is almost empty. Shaw discharged water to the pond over the weekend. During the month, there were no major problems. The plant did have a freeze which knocked the system off for a short time. They have a roll off box of filter cake ready to dispose March 13, 2007, when Rose will be onsite to sign the manifest. Scott and Ray repaired the Army trailer plumbing that broke during freezing conditions.

The MNA sampling event is starting February 19, 2007. Creek sampling results from the end of December 2006 sampling data indicated non detect for perchlorate at 5 locations. Three were located in Harrison Bayou and 2 in Goose Prairie Creek. The map showing the sampling locations and data will be provided soon.

Fay Duke expressed concern over the calibration used in the MNA modeling. Praveen Srivastav said that “calibration” for this modeling was not the correct term and that a “field verification” check was conducted to compare simulated model results at appropriately located wells with actual observed results.

Fay expressed her concern over the groundwater modeling report and its relationship to the requirements for surface water monitoring at individual sites. Fay asked if surface water then would not be monitored at individual sites where the model predicts no impact. Rose answered in the affirmative for TERC sites. Praveen said that Shaw will monitor the surface water at one location if the extraction system is turned off to evaluate MNA at Site 16.

Draft Final Feasibility Study LHAAP-16 report is being prepared. Fay Duke asked if groundwater is included in this FS. The answer was yes. No BERA impact is expected on the LHAAP-16 FS because the site is a landfill with a RCRA cover.

Defense Environmental Restoration Program (DERP) TERC Update (Praveen Srivastav and John Elliott)

For Sites 48 and 53, Praveen Srivastav indicated that the risk assessment appendices to the Site Evaluation Report are being revised and will be submitted this Thursday, 2/15/07, for an advance regulatory review before the report is finalized. Data from the new well at LHAAP-48 will be inserted in main text of the evaluation report.

For LHAAP-12, the information collected from the new wells will be included in LHAAP-12 Well Abandonment/Installation report. VOC (i.e. TCE, DCE) concentrations found in the new well 12WW24 were similar to the well 12WW12 that was abandoned. Two rounds of MNA data have been collected. The first set has already been provided to regulators for review in the MNA Evaluation Report for Sites 12, 37 and 67. The data from the most recent round completed in December 2006 will be submitted to the regulators soon. Rose provided a brief explanation as to why a number of TERC sites are following what seems to be a disjointed and convoluted path to remedy. In response to EPA’s comments many sites are now looking at MNA as an option. Rose reminded the stakeholders that originally ACL was used but EPA made a comment on the ROD saying that ACL could no longer be used and that it must demonstrate that the selected remedy would achieve MCL. EPA requested that the Army estimate the time to MCL. The MNA modeling was conducted to address that comment. Subsequently, MNA data was collected to determine if conditions suitable for MNA existed at the site. Similar comments for LHAAP-37/67 were anticipated so these sites were also modeled to obtain estimated time to reach MCL and field data was collected to support MNA as a remedy.

New wells were installed at LHAAP-37/67. Rose made a clarification regarding groundwater flow direction and will respond in the RTC so that the explanation will be in the Admin Record.

The LHAAP-59 document got passed around at EPA and was reassigned. It was requested that EPA review and comment.

The Army received comments on Data Gaps report from Fay. Some of these responses to these comments are found in meeting minutes from 2002 and 2003. Rose said she will pass on.

MMRP Update

John Lambert said that the draft EE/CA comment/response table will be available by the end of the week. They expect a resolution within the next week or two. They would finish this discussion outside of this meeting.

IAP is scheduled for April 3 and 4 hosted by Shaw's Houston office. Participants expected tentatively are 3 from EPA, 2 from TCEQ, 2 from FWS, 3 or 4 from Army, and 4 from Shaw. The time of the meeting is estimated at 8AM both days and is expected to run about a day and a half.

Schedule

The date of RAB meeting has been changed to the 13th of March. A potluck dinner by the community has been planned. Shaw will send out an email notification that this change was made. A teleconference for the monthly managers meeting in March is scheduled for March 6, 2007, 1:00 PM.

Chris Villarreal requested a schedule covering several years. Dave Cobb stated that Shaw can either provide the schedule in PDF format or in another format that is compatible with EPA's system. Chris indicated that he and others at EPA use MS Project. Dave said that he would look into getting the Primavera schedule converted to MS Project.

Transfer Update

The Army has EPA comments on ECOP IV and the document is being revised and has gone to BRAC legal for signature then will be sent to USFWS. ECOP III had 100 acres. There are 740 acres to be transferred with this ECOP III and IV and that puts the total transfer to close to 7000 acres. This latest document includes acreage from Plant 2 and 3 areas and the EFIA.

BRAC will have no need for electricity after March 14, 2007 (when security is removed from the front gate.) Rose indicated that if the power is off, the front gates won't open. Currently AEC is picking up the electric on the fire station building. At present USFWS still does not have separate power. There are currently 4 phone lines – one at the Longhorn trailer, one at the fire station, and 2 at the gate (one of these is on the gate). These will be discontinued after March 14.

Pits and Hazard Abatement

Nothing new to discuss at this time.

Demo Landfill

Discussions with the TCEQ and Army have resulted in the appropriate steps in regards to the closing of this landfill. Another inspection is needed and hopefully can be conducted in March, 2007. If not March, then the inspection would be kicked back until July 2007. Rose mentioned that a form will be prepared by BRAC with a letter to the state and will require a ROD and PP. Rose said a summary of what they talked about will be provided via email to Steve Tzhone.

Meeting Adjourned.

Action Items:

Army

- Provide 5-year review excerpt for LHAAP-16
- Forward MMRP report to EPA and TCEQ when available.

Shaw

- Send creek sampling results and figure to stakeholders
- Provide long range schedule for EPA in MS-Project compatible format

EPA

- Steve Tzhone will forward the MNA guidance when it becomes available.



**Status of Technical Documents – 4 week look ahead
Longhorn Army Ammunition Plant – PBC Contract
March 06, 2007**

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USACE/ Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
ERA									
1	Draft Step 3 report (Vol I of BERA)	1/16/07		x	2/15/07		Under regulatory review		As discussed, report will be issued in two parts to expedite review. BERA (Volume 2) will follow later due to sampling analysis durations.
2	Draft BERA (Vol II of BERA)	1/31/07	x		2/16/07	In progress	Army comments received, resolution in progress		
ENVIRONMENTAL									
3	Draft Final SI/Evaluation Report, LHAAP-02	3/30/06		x			Comments rec'd from TCEQ 8/29/06. EPA comments rec'd 5/12/06.	x	Final will be issued when ERA information available.
4	Draft Final Proposed Plan, LHAAP-60	7/7/06		x			Comments rec'd from TCEQ 8/1/06. EPA comments rec'd 8/21/06.	x	Final to be submitted when ERA information available.
5	LHAAP-18/24 GWTP Sampling Optimization Memo	11/15/06		x	12/16/06		Under Stakeholders review	x	Comments pending from both TCEQ and EPA
6	Draft Final TCRA Memo – LHAAP-04, -49, -50, and Pistol Range	12/6/06	x				Under Army review		Currently undergoing resolution
7	Perimeter Well Sampling Optimization Memo	12/28/07		x	1/27/07		Comments received 2/6/07		Under Shaw review.
8	Draft Feasibility Study, LHAAP-58	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.



**Status of Technical Documents – 4 week look ahead
Longhorn Army Ammunition Plant – PBC Contract
March 06, 2007**

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USACE/ Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
9	Draft Feasibility Study, LHAAP-17	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.
10	Draft Feasibility Study, LHAAP-16	11/30/06	x		12/18/06 (Army)		Complete		
10	Draft Final Feasibility Study, LHAAP-16	TBD					On hold pending review of MNA evaluation proposal		Can not be finalized until eco issues resolved/ ERA further along.
11	Draft Final SI Report for LHAAP-06, 07, -51, -55, -64, -66, -68 (combined)	1/11/07		x	2/10/07		In regulatory review	x	
12	Draft SI Report for LHAAP-35/36	3/15/07 (Army)					In preparation		Report that summarizes sampling data for sumps
13	Quarterly GWTP Report	1/31/07 (Army)	x	X			Complete		
14	Draft LHAAP-16 MNA Evaluation Proposal	2/21/07 (Army)	x				Complete		In Army review

Technical Document Status Table
TERC Task Order NO. 0109
Longhorn Army Ammunition Plant

00043531

No.	Site	Documents in Progress	Draft Document				Draft Final Document									Final Document
			Draft Submittal Date	Army Comments	Shaw RTC	Comment Resolution	Draft Final Submittal Date	AEC Comments	EPA Comments	TCEQ Comments	Shaw RTC	Army Comments	Comment Resolution	Army forward RTC to TCEQ & EPA	Comment Resolution	Final Submittal Date
1	LHAAP-12	Remedial Design Addendum, Rev 03, LHAAP-12	07/14/06	08/11/06			08/17/06	None Required	09/05/06							
2	LHAAP-12	Well Abandonment and Installation Report, LHAAP-12					06/07/06	None Required	07/17/06	09/27/06	10/19/06	10/31/06	11/07/06	11/20/06	TCEQ _____ EPA _____	
3	LHAAP-12	Results of Modeling for Natural Attenuation of TCE, LHAAP-12					05/15/06	None Required								
4	LHAAP-32	Proposed Plan, LHAAP-32					07/21/06	08/25/06	09/05/06	09/12/06	09/19/06			11/21/06	TCEQ 12/07/06 EPA 01/26/07	
5		Evaluation of Perimeter Well Data for use as Groundwater Background					03/07/06	None Required	04/19/06	10/24/06	11/07/06	RMZ 11/07/2006 USACE 11/20/06	11/20/06	11/21/06	TCEQ 12/07/06 EPA 02/21/07	
6		Data Gaps Investigation Report					05/18/05	None Required	05/17/06	10/24/06	11/07/06	RMZ 11/09/2006 USACE 11/20/06	11/28/06	11/29/06	TCEQ 02/28/07 EPA 12/06/06	
7	LHAAP-48/53	Site Evaluation Report, LHAAP-48/53					03/10/06	None Required	04/20/06	07/06/06	10/27/06	10/31/06	10/31/06	11/02/06	EPA concur 11/03/06 TCEQ comments 11/13/06	
8	LHAAP-48/53	Revised Proposed Plan, LHAAP-48/53	09/25/06	10/31/06	11/14/06	01/12/07										
9	LHAAP-37/67	Proposed Plan, LHAAP-37/67	05/02/06	05/24/06	06/06/06	06/22/06	07/18/06	08/25/06	09/05/06	09/20/06	10/19/06	10/31/06	11/07/06	11/21/06	TCEQ _____ EPA 02/21/07	
10	LHAAP-37/67	Natural Attenuation Modeling Report, LHAAP-37/67	09/22/06	10/13/06	10/27/06	10/31/06	11/14/06									
11	LHAAP-08	Proposed Plan, LHAAP-08	05/01/06	05/24/06			07/07/06	08/25/06	08/21/06	09/20/06	09/29/06			11/21/06	TCEQ 12/07/06 EPA 02/21/07	
12	LHAAP-59	Site Investigation Report, LHAAP-59	11/02/06	11/07/06	11/09/06	11/15/06	11/21/06	None Required		01/11/07						
13	LHAAP-12/37/67	Natural Attenuation Evaluation, LHAAP-12/37/67	10/31/06	11/30/06	12/08/06	12/08/06	12/15/06	None Required								
14	LHAAP-12/37/67	Memorandum regarding MNA Evaluation, LHAAP-12, 37, & 67	02/15/07	02/16/07	02/16/07	02/16/07	02/16/07									
15		Final Modeling Report (Revision 1)														02/09/07

Shaw Forecasted Submittal Date

Shaw Action Item

Army Action Item

EPA & TCEQ Action Item

LONGHORN ARMY AMMUNITION PLANT,**Karnack, Texas*****MONTHLY MANAGERS' MEETING*****AGENDA**

DATE: Tuesday, 13 February 2007
TIME: 1:00 – 3:00 p.m.
PLACE: Teleconference – **Call-in-Number: 877-797-9304, Passcode 4155734**

1:00 Welcome **RMZ**
 New Tulsa PM, John Lambert

1:05 Review of January Meeting Minutes and Action Items **RMZ**
Shaw PBC

- Inform Jeff Armstrong regarding expected end of February 2007 submittal date of BERA Vol. II so he can inform Larry Tannenbaum
- Set up a conference call with TCEQ and EPA to discuss GWTP sampling modification memo
- Shaw to submit a memo presenting information to support the proposal to shut down extraction wells at LHAAP-16
- Send an e-mail with proposed day and time for weekly or biweekly call with regulators
- Provide a brief tech/design memo summarizing re-injection system at LHAAP-18/24 for Shaw's use in the field and for information to Army and regulators

Shaw TERC

- Send response to comments on LHAAP-32 and 37/67 proposed plans to Raji Josiam (EPA) with copy to Chris Villarreal
- Send a revised table of MNA results, incorporating the Dec 2006 data, to EPA and TCEQ
- Send revised risk evaluation for LHAAP-48/53 electronically to TCEQ with copy to EPA
- Shaw and Army to decide how to roll up MNA data and modeling for LHAAP-37 and 67 and inform regulators

Army

- Cliff Murray to look up any documentation or background information that supported installation of extraction system at LHAAP-16. Also check with Jeff Armstrong to see if he has any information.
- Rose Zeiler to send EPA CID email re mercury at Demolition LF

TCEQ

- Dale Vodak/Fay Duke to find out requirements for IHW permit for the landfill at LHAAP-19
- Dale Vodak/Fay Duke to check on the permit requirements, if any, for dewatering of pits and use of a portable air stripping unit
- Fay Duke to provide comments on perimeter well sampling frequency memo
- Fay Duke to provide comments or concurrence for LHAAP-18/24 GWTP Sampling Modification Memo based on the outcome of the call (to be scheduled, see Shaw's action item)

EPA

- Raji Josiam to confirm the availability of conference room for February 13, 2007 monthly managers' meeting in Dallas
- Raji Josiam to check with Chris Villarreal regarding the status of ECOP IV review by EPA and inform Rose Zeiler
- Raji Josiam to check on the schedule for the EPA website on Longhorn
- Chris Villarreal to call Susan Roddy and Marc Greenberg to make sure that the review of the BERA is on their schedule
- Steve Tzhone to check on MNA and OPS requirements.

1:30	Defense Environmental Restoration Program (DERP) PBC Update	
	<ul style="list-style-type: none">• Document Status/Environmental Sites (Table)• BERA update• GWTP update• Creek sampling results• GWTP/MNA Sampling• LHAAP-18/24 – Optimization design• LHAAP-16 – extraction system shut down, MNA sampling, feasibility study addendum• Status of Site Evaluation Report, LHAAP-6, 7, 51, 55, 64, 66, 68	
2:00	DERP Total Environmental Restoration Contract Update	PS
	<ul style="list-style-type: none">• Documents Status/Environmental Sites (Table)• LHAAP-48/53 update• LHAAP-12 update• LHAAP-37/67 update• Approach to MNA modeling and MNA evaluations	
2:20	MMRP Update	CM
2:30	Schedule – IAP (Who will attend?), March Managers & RAB Meetings (Shaw to confirm Community Center available on date change)	JL/CM
2:40	Transfer Update ECOP IV End of Security Contract – Gate Access Pits and Hazards Abatement Demolition Landfill	RMZ
3:00	Adjourn	RMZ



United States Department of the Interior



FISH AND WILDLIFE SERVICE

Caddo Lake National Wildlife Refuge

P.O. Box 230

Karnack, TX 75661-0230

Phone: 903.679.9144 – Fax: 903.679.9148

E-Mail mark_williams@fws.gov

February 15, 2007

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

Dear Rose:

This letter is in response to e-mail, dated 2/14/07, concerning the Refuge's future plans for the Signal Test and South Test Areas on LHAAP.

The Caddo Lake National Wildlife Refuge (Refuge) can accommodate the level of public use on these two areas to whatever standard the U.S. Army (Army) deems appropriate. Installation of fencing, signage and other public use controls for dealing with health and safety issue may be required for the visiting public in the future. The Army is ultimately responsible for liability on these two areas (whether administered by the Army or the Refuge) and the Refuge will assist the Army with whatever controls it decides are necessary.

Refuge employees and their assigns will, in the future, access and utilize the areas unabated. The Refuge will control and complete management activities, conduct research, and perform law enforcement functions on the two sites once the administrative transfer is complete.

The Refuge will complete habitat management activities on the areas on a regular and reoccurring basis. These activities include prescribe fire activities, forest thinning (mechanized), and pest control as examples. If the Army decides the area can be open to the public, the Refuge will allow all of the "big six" public use activities that are compatible with the purpose and mission of the Refuge (hunting, fishing, wildlife observation, wildlife photography, wildlife education and wildlife interpretation). Any restrictions on implementation of the "big six" activities on these two sites will be coordinated with the Army prior their establishment.

00043535

I hope this letter clarifies the Refuge plans for the future management, use and access of the Signal Test and South Test Areas on the LHAAP. If you have any questions or if I can be of further assistance concerning this matter, please contact me at (903) 679-9144 or (903) 407-0852.

Sincerely,

Mark Williams

Mark Williams
Refuge Manager





**Subject: Draft Final Minutes, Monthly Managers Meeting,
Longhorn Army Ammunition Plant (LHAAP)**

Location of Meeting: Teleconference

Date of Meeting: March 6, 2007, 1:00 PM – 3:30 PM

Meeting Participants:

BRAC:	Rose M. Zeiler
USACE-Tulsa:	Cliff Murray, John Lambert
USAEC	Jeff Armstrong
Shaw Environmental:	Dave Cobb, Praveen Srivastav, John Elliott, Van Vangala, Kay Everett, Greg Jones, Bob Culbertson
USEPA Region 6:	Chris Villarreal, Steve Tzhone, Scott Harris, Raji Josiam
TCEQ:	Fay Duke
USFWS:	Paul Bruckwicki, Barry Forsythe

Prior to the meeting Shaw and Army had distributed via e-mail: meeting agenda, minutes of February 13, 2007 Monthly Managers' Meeting, and the document status tables for the TERC and PBC projects.

Stephen Tzhone informed the group that he has been assigned as the primary EPA remedial project manager for Longhorn, replacing Chris Villarreal. Chris has many projects and some of his other projects have become very active. Steve requested a meeting so he has an idea of the responsibilities, document schedules and goals for each site. Rose Zeiler suggested meeting the following week before or after the RAB meeting. She suggested that, during the meeting, she would also go over site access issues after security has been removed from the front gate on March 14, 2007. The meeting was scheduled for the morning of March 14, 2007 at 9 AM.

Shaw Action Items from 13 Feb 2007 Managers' Meeting:

Shaw PBC

- **Send creek sampling results and figure to stakeholders:** Sent out by Greg Jones on 1 Mar 2007.
- **Provide long range schedule for EPA in MS-Project compatible format:** Dave Cobb provided a PDF file on 6 Mar 2007. Praveen Srivastav inquired if EPA was looking for a 1 year, 5 year or 10 year schedule. Steve Tzhone indicated that a 5-year look ahead was needed and said he would check with his headquarter to see what else would be needed. Dave said that Shaw uses Primavera and they are still working on converting the schedule to a form that EPA can use and that it might take some time.

Army Action Items:

- **Forward MMRP report to EPA and TCEQ when available:** Report was not available as of the time of the meeting.
- **Forward LHAAP-59 Report and other RTCs to EPA:** Sent out by Rose Zeiler on 15 Feb 2007.

EPA Action Items:

- **Provide 5-year review excerpt for LHAAP-16:** Sent out by Chris Villarreal on 13 Feb 2007.
- **Steve Tzhone will forward the MNA guidance when it becomes available:** Regarding the 1999 Guidance, Chris Villarreal said that there was an update. He also indicated that technical guidance documents on metals MNA and capture zone analysis are expected to be out soon. On 14 Feb, Steve provided links to websites concerning information on OPS, MNA and MNA remedies. Steve will send out updated information on MNA guidance.
- **Reports in EPA Review:** A few outstanding reports are in review with Raji Josiam and Scott Harris who are assisting Steve.

Defense Environmental Restoration Program (DERP) PBC Update (Dave Cobb/Praveen Srivastav)

Dave Cobb briefly went over the highlights on the document status table. He indicated that BERA Volume II document was being shipped out on the day of the meeting (March 6) and that the stakeholders should receive it the next day.

GWTP. Van Vangala indicated that there were no major problems at the Groundwater Treatment Plant (GWTP) and that operations were proceeding normally. Shaw is discharging water currently to the creek since there is still flowing water in Harrison Bayou. Over the weekends, the water is discharged to the INF pond, and then released to Harrison Bayou on the following Mondays after flow is verified. There were 3 call outs, outside of normal operating hours. One of the calls pertained to a power outage and the others were due to mechanical issues (pumps freezing). A roll off of filter cake material is scheduled for disposal on March 14, 2007, when Rose Zeiler is expected to be onsite to sign the manifest.

Creek Sampling Results. Samples collected during December 2006 indicated nondetect for perchlorate at 3 locations in Harrison Bayou. Five sampling locations were initially identified with 3 sample locations in Harrison Bayou and 2 in Goose Prairie Creek. However, no samples could be collected from Goose Prairie Creek because there was no flow in the creek at the time of sampling. A map showing the sampling locations and a table of data were provided to the stakeholders prior to the meeting.

Fay Duke asked a question as to how the creek sampling locations were picked. Praveen Srivastav and Rose Zeiler replied that locations were based on previous locations sampled by USACE and that they were approved by regulators prior to the sampling by Shaw. The sampling is a continuation of the sampling program conducted by the USACE.

GWTP/MNA Sampling. Shaw completed the sampling of wells at LHAAP-18/24 and MNA sampling at a number of sites (e.g. LHAAP-17, 29, 46, 47, 58) in February; 2007. MNA sampling at LHAAP-16 was not conducted because the proposal to shut down the system in order to sample for MNA was with the Army for review. The proposal is to be submitted to the regulators after Army's review and comment resolution.

LHAAP-18/24 optimization Design. The optimization design plan was scheduled to go out to for the Army's review in 1-2 weeks.

LHAAP-16 Extraction System Shut Down/MNA Sampling Proposal. As indicated above, the proposal was in Army's review at the time of the meeting. It would be submitted to the regulators after Army's review and comment resolution.

Status of Site Investigation (SI) Report for LHAAP-06, -07, -51, -55, -64, -66, and -68.

The report was awaiting comments from TCEQ and EPA. Steve Tzhone planned to talk with TCEQ later in the day and expected to send EPA's comments in 1-2 weeks. Fay Duke indicated that she had not reviewed the document because she had a lot of TERC site documents to review.

Defense Environmental Restoration Program (DERP) TERC Update (Praveen Srivastav/John Elliott)

Refer to Document Status Table:

1. Remedial Design Addendum for LHAAP-12 was pending Fay's review.
2. Fay Duke indicated that she was reviewing the RTC on LHAAP-12 well abandonment and MNA reports. She indicated that she was looking at all of them and that she had a few minor comments on the design document.
3. Fay asked Rose to send her the July 26, 2006 submittal of the "Results of Modeling for Natural Attenuation of TCE, LHAAP-12", but then noted that since it had been sent electronically she would have it already.
4. Shaw was resolving comments on Proposed Plan for LHAAP-32 and planned to submit to the Army electronically by the Friday of the week (March 9). Shaw was also working on items no. 9 and 11, Proposed Plans for LHAAP-08 and LHAAP-37/67. Shaw to send RTC for LHAAP-37/67 proposed plan by March 7.
8. The site evaluation report for LHAAP-48/53 and the Proposed Plan were to go out with revised RTC.

LHAAP-48/53 Monitoring Well Abandonment. Rose Zeiler stated that the Army planned to abandon all wells at LHAAP48/53, including those with stainless steel casings, under the PBC. However, that might not happen for many years. Rose Zeiler asked the regulators if they preferred to have the stainless steel wells abandoned sooner. She asked if the regulators saw an urgency to the abandonment of the stainless steel wells. Rose said that if the wells had to be abandoned soon, then the Army would have to find funds under the TERC for the abandonment. Fay Duke indicated that the wells should be abandoned as soon as possible now

that they have been identified as a source of contamination. EPA agreed. Rose asked USACE to look into funding this activity.

LHAAP-12 Update. Fay Duke said the RTCs for the well abandonment report were good and put everything into context. She asked if the Army could put the RTC in the report. Rose replied that the Army would make the RTCs a part of the document by placing them in an appendix along with the hand drawn maps. TCEQ agreed.

Rose indicated that approach for the proposed plans for LHAAP-37/67, 08, and 32 was similar. The Army will hold them as draft final until the BERA is completed. At that time the results of the BERA will be incorporated into these documents and the documents finalized.

MMRP Update

John Lambert said that the contractor was completing the RTC for the draft EE/CA. Resolution of the comments was expected in about a week and then the document would be revised. John indicated that the Army should get the revised document in 1-2 weeks.

Schedule

IAP is scheduled for April 3 and 4 hosted by Shaw's Houston office. A part of the time will be used as the monthly managers meeting. Rose indicated that the IAP workshop would begin at 9:00 AM on April 3rd and is expected to conclude by noon on April 4th. Cliff Murray informed that the IAP contractor for AEC had its own wireless access and would not be dependent upon access to Shaw's network.

Transfer Update.

Electric Utilities. Rose Zeiler indicated that she had been under the impression that there was no Army action required for SWEPCO to install the power lines to the Admin Area and Fire Station for USFWS. However, she found out recently that USFWS decided to use existing power lines instead of building new ones as originally planned. Now SWEPCO will need an easement from Army for the use of the existing line where it lies on Army land along the way to the Fire Station. They prefer installing both sections of the line (the one to the Admin Area and the one to the Fire Station) at the same time, instead of in two actions. As soon as USFWS begins paying for their own power, Army will transfer the Fire Station to them. The Army will have to check with TCEQ regarding their air quality station to see to make them aware of the situation.

Paul Bruckwicki said that the administration building infrastructure has been transferred to SWEPCO. SWEPCO is waiting on an easement from the gate to the Fire Station and then to the GWTP. However Rose Zeiler noted that SWEPCO has not yet cleared the USFWS easement through their legal. Army and GSA have initiated paper work for that easement. Shaw needs to discuss with USFWS as to how to cover the power for the extraction wells. More discussion is needed.

ECOP IV. The public review period for ECOPIV has started. The public review is not typically done for ECOPs but it seemed like a good idea here because there is such strong public interest.

Security contract. Army's contract for the security at the front gate ends on March 14. At that time some of the phone lines may be taken over by USFWS, as has been expressed previously by Mark Williams (of USFWS) who still intends to use the card access reader. All the card files will be turned over to Mark along with all the paperwork that Jim, the security guard, has maintained. Jim can explain the process to USFWS.

Pits and Hazards.

Nothing new to report.

Refuge Opening

Rose Zeiler indicated that tours on Army land may begin as soon as a tour map has been received and approved by Tom Lederle. It had not been received as yet, so no tours should be taking place at this time.

TVA was scheduled for the week of March 25th to conduct their flyover and water level measurements.

Meeting Adjourned.

Action Items:

Army

- Forward MMRP report to EPA and TCEQ when available.

Shaw

- Provide map and hotel information for IAP meeting in April, 2007.
- Send current schedule to EPA and TCEQ.

EPA

- Steve Tzhone to forward the MNA guidance when it becomes available.

Perchlorate Sample Results
Harrison Bayou and Goose Prairie Creek¹
December 20, 2006

LOCATION CODE				HBW-1				HBW-10				HBW-7			
SAMPLE NO				HBW-1-122006				HBW-10-122006				HBW-7-122006			
SAMPLE DATE				20-Dec-06				20-Dec-06				20-Dec-06			
SAMPLE PURPOSE				REG				REG				REG			
Test Group	Parameter	Units	Filtered	Result	Qualifier	Validation		Result	Qualifier	Validation		Result	Qualifier	Validation	
PERC	Perchlorate	µg/L	N	1	U	U		1	U	U		1	U	U	

Notes

¹The proposed Goose Prairie Creek sample locations (GPW-1 and GPW-3) were not sampled due to lack of flow in the creek.

N not filtered

U below detection limit; result is detection limit
µg/L microgram per liter



▲ Surface Water Sampling Location

Stream

Road

Site

Lake



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

FIGURE 1

SURFACE WATER SAMPLING LOCATION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Plot Date: 11/06



**Status of Technical Documents – 4 week look ahead
Longhorn Army Ammunition Plant – PBC Contract
March 06, 2007**

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USACE/ Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
ERA									
1	Draft Step 3 report (Vol I of BERA)	1/16/07		x	2/15/07		Under regulatory review		As discussed, report will be issued in two parts to expedite review. BERA (Volume 2) will follow later due to sampling analysis durations.
2	Draft BERA (Vol II of BERA)	1/31/07	x		2/16/07	In progress	Army comments received, resolution in progress		
ENVIRONMENTAL									
3	Draft Final SI/Evaluation Report, LHAAP-02	3/30/06		x			Comments rec'd from TCEQ 8/29/06. EPA comments rec'd 5/12/06.	x	Final will be issued when ERA information available.
4	Draft Final Proposed Plan, LHAAP-60	7/7/06		x			Comments rec'd from TCEQ 8/1/06. EPA comments rec'd 8/21/06.	x	Final to be submitted when ERA information available.
5	LHAAP-18/24 GWTP Sampling Optimization Memo	11/15/06		x	12/16/06		Under Stakeholders review	x	Comments pending from both TCEQ and EPA
6	Draft Final TCRA Memo – LHAAP-04, -49, -50, and Pistol Range	12/6/06	x				Under Army review		Currently undergoing resolution
7	Perimeter Well Sampling Optimization Memo	12/28/07		x	1/27/07		Comments received 2/6/07		Under Shaw review.
8	Draft Feasibility Study, LHAAP-58	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.



**Status of Technical Documents – 4 week look ahead
Longhorn Army Ammunition Plant – PBC Contract
March 06, 2007**

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USACE/ Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
9	Draft Feasibility Study, LHAAP-17	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.
10	Draft Feasibility Study, LHAAP-16	11/30/06	x		12/18/06 (Army)		Complete		
10	Draft Final Feasibility Study, LHAAP-16	TBD					On hold pending review of MNA evaluation proposal		Can not be finalized until eco issues resolved/ ERA further along.
11	Draft Final SI Report for LHAAP-06, 07, -51, -55, -64, -66, -68 (combined)	1/11/07		x	2/10/07		In regulatory review	x	
12	Draft SI Report for LHAAP-35/36	3/15/07 (Army)					In preparation		Report that summarizes sampling data for sumps
13	Quarterly GWTP Report	1/31/07 (Army)	x	X			Complete		
14	Draft LHAAP-16 MNA Evaluation Proposal	2/21/07 (Army)	x				Complete		In Army review

Technical Document Status Table
TERC Task Order NO. 0109
Longhorn Army Ammunition Plant

00043545

No.	Site	Documents in Progress	Draft Document				Draft Final Document									Final Document
			Draft Submittal Date	Army Comments	Shaw RTC	Comment Resolution	Draft Final Submittal Date	AEC Comments	EPA Comments	TCEQ Comments	Shaw RTC	Army Comments	Comment Resolution	Army forward RTC to TCEQ & EPA	Comment Resolution	Final Submittal Date
1	LHAAP-12	Remedial Design Addendum, Rev 03, LHAAP-12	07/14/06	08/11/06			08/17/06	None Required	09/05/06							
2	LHAAP-12	Well Abandonment and Installation Report, LHAAP-12					06/07/06	None Required	07/17/06	09/27/06	10/19/06	10/31/06	11/07/06	11/20/06	TCEQ _____ EPA _____	
3	LHAAP-12	Results of Modeling for Natural Attenuation of TCE, LHAAP-12					05/15/06	None Required								
4	LHAAP-32	Proposed Plan, LHAAP-32					07/21/06	08/25/06	09/05/06	09/12/06	09/19/06			11/21/06	TCEQ 12/07/06 EPA 01/26/07	
5		Evaluation of Perimeter Well Data for use as Groundwater Background					03/07/06	None Required	04/19/06	10/24/06	11/07/06	RMZ 11/07/2006 USACE 11/20/06	11/20/06	11/21/06	TCEQ 12/07/06 EPA 02/21/07	
6		Data Gaps Investigation Report					05/18/05	None Required	05/17/06	10/24/06	11/07/06	RMZ 11/09/2006 USACE 11/20/06	11/28/06	11/29/06	TCEQ 02/28/07 EPA 12/06/06	
7	LHAAP-48/53	Site Evaluation Report, LHAAP-48/53					03/10/06	None Required	04/20/06	07/06/06	10/27/06	10/31/06	10/31/06	11/02/06	EPA concur 11/03/06 TCEQ comments 11/13/06	
8	LHAAP-48/53	Revised Proposed Plan, LHAAP-48/53	09/25/06	10/31/06	11/14/06	01/12/07										
9	LHAAP-37/67	Proposed Plan, LHAAP-37/67	05/02/06	05/24/06	06/06/06	06/22/06	07/18/06	08/25/06	09/05/06	09/20/06	10/19/06	10/31/06	11/07/06	11/21/06	TCEQ _____ EPA 02/21/07	
10	LHAAP-37/67	Natural Attenuation Modeling Report, LHAAP-37/67	09/22/06	10/13/06	10/27/06	10/31/06	11/14/06									
11	LHAAP-08	Proposed Plan, LHAAP-08	05/01/06	05/24/06			07/07/06	08/25/06	08/21/06	09/20/06	09/29/06			11/21/06	TCEQ 12/07/06 EPA 02/21/07	
12	LHAAP-59	Site Investigation Report, LHAAP-59	11/02/06	11/07/06	11/09/06	11/15/06	11/21/06	None Required		01/11/07						
13	LHAAP-12/37/67	Natural Attenuation Evaluation, LHAAP-12/37/67	10/31/06	11/30/06	12/08/06	12/08/06	12/15/06	None Required								
14	LHAAP-12/37/67	Memorandum regarding MNA Evaluation, LHAAP-12, 37, & 67	02/15/07	02/16/07	02/16/07	02/16/07	02/16/07									
15		Final Modeling Report (Revision 1)														02/09/07

Shaw Forecasted Submittal Date

Shaw Action Item

Army Action Item

EPA & TCEQ Action Item

LONGHORN ARMY AMMUNITION PLANT,

00043546

Karnack, Texas

MONTHLY MANAGERS' MEETING

AGENDA

DATE: Tuesday, 06 March 2007
TIME: 1:00 – 3:00 p.m.
PLACE: Teleconference – **Call-in-Number: 866-797-9304, Passcode 4155734**

1:00 Welcome **RMZ**
Change in EPA POC

1:05 Review of February 2007 Meeting Minutes and Action Items **RMZ**
Shaw PBC
- Send creek sampling results and figure to stakeholders
- Provide long range schedule for EPA in MS-Project compatible format
Army
- Provide 5-year review excerpt for LHAAP-16
- Forward MMRP report to EPA and TCEQ when available
- Forward Site 59 Report and other RTCs to EPA
EPA
- Steve Tzhone will forward the MNA guidance when it becomes available

1:30 Defense Environmental Restoration Program (DERP) PBC Update **DC/PS**

- Document Status/Environmental Sites (Table)
- BERA update
- GWTP update
- Creek sampling results
- GWTP/MNA Sampling
- LHAAP-18/24 – Optimization design
- LHAAP-16 – Extraction system shut down/MNA sampling proposal
- Status of Site Evaluation Report, LHAAP-6, 7, 51, 55, 64, 66, 68

2:00 DERP Total Environmental Restoration Contract Update **PS/JE**

- Documents Status/Environmental Sites (Table)
- LHAAP-48/53 monitoring well abandonment
- LHAAP-12 update
- LHAAP-37/67 update

2:20 MMRP Update **CM**

2:30 Schedule – IAP, March Managers & RAB Meetings

JL/CM

2:40 Transfer Update

RMZ

Electrical Utilities

ECOP IV progress

End of Security Contract – Gate Access

Pits and Hazards Abatement

3:00 Adjourn

RMZ



**Subject: Draft Final Minutes, Monthly Managers Meeting,
Longhorn Army Ammunition Plant (LHAAP)**

Location of Meeting: Shaw offices, Houston, Texas

**Date of Meeting: April 4, 2007, 08:00 PM – 11:30 PM
Post IAP Work Shop**

Meeting Participants:

BRAC:	Rose M. Zeiler
USACE-Tulsa:	Cliff Murray, John Lambert, Rick Smith
USAEC	Jeff Armstrong
Shaw Environmental:	Dave Cobb, Praveen Srivastav, John Elliott, Van Vangala, Kay Everett, Greg Jones, Frank Eidson, Amar Bumb (phone)
USEPA Region 6:	Steve Tzhone, Scott Harris (phone), Raji Josiam (phone)
TCEQ:	Fay Duke
USFWS:	Paul Bruckwicki, Barry Forsythe

Prior to the start of the meeting, Jeff Armstrong led a discussion on some funding issues regarding TERC and MMRP. He mentioned that the AEC has earmarked money for MMRP for this fiscal year. Rose Zeiler stated that Shaw's rate adjustment on the TERC task order has resulted in the overall cost for the task order to be higher than previously known. This may make it difficult to complete the scope of work with available funds. Rick Smith said that money can be added to the Longhorn TERC task order with a modification as long as the scope of work does not change.

Rose Zeiler asked Steve Tzhone if a NFA ROD can be submitted for the MMRP sites following an NTCRA Action Memorandum without having to go through a proposed plan. Steve Tzhone said he would check on this. He further added that while the Action Memo can normally be the final decision document, LHAAP is an NPL site and may require a ROD because of that. Rose said that Army requires a ROD after a removal action for NPL sites. Praveen Srivastav asked how the use of a non-TCRA was justified for MMRP work. Rose responded that UXO was a safety issue, especially with the public asking for access. It is within DOD's removal authority. Praveen asked if Army legal may foresee a problem using non-TCRA. Jeff Armstrong replied that this approach can be used in other places if successful and they were moving very carefully through this process.

There was a short discussion regarding the utilities at the installation. Rose Zeiler stated that the details are yet to be ironed out with SWEPCO, Shaw, AEC, and Tulsa Corps regarding line installation and payment.

Action Items from 6 March 2007 Managers Meeting

Army Action Items:

- **Forward MMRP report to EPA and TCEQ when available:** Report was not available at the time of the meeting and is currently due out at the end of April 2007.
- **Forward March 2007 Monthly Manager's Meeting minutes to stakeholders:** Rose Zeiler will forward to team.

EPA Action Items:

- **Steve Tzhone to forward the MNA guidance when it becomes available.** Steve forwarded links to the 2004 guidance.

Shaw Action Items:

- **Send current schedule to EPA and TCEQ:** Sent out by Dave Cobb.

Defense Environmental Restoration Program (DERP) PBC Update (Dave Cobb/Praveen Srivastav)

Dave Cobb briefly went over the highlights on the document status table. EPA's Steve Tzhone indicated that Susan Roddy, Marc Greenberg, Vicki Reat (TCEQ), and Barry Forsythe (USFWS) are planning to get comments back on the BERA Volume II by April 23. They have some internal calls to make to each other and may invite Shaw on these calls to see what comments are coming up and hopefully get some questions resolved.

GWTP. Van Vangala indicated that there were no major problems at the Groundwater Treatment Plant (GWTP) last month and that operations were proceeding normally. Filter cake was disposed within the last month. The INF pond is still empty and there is water in the creek. An excursion took place on March 6 for perchlorate with a value of 53 ppb. It was ND on March 5 and March 7. Shaw is investigating the reason for the excursion. The FBR will be serviced within the next few weeks.

Rose Zeiler asked if there have been any unwanted visitors at the plant. Van Vangala responded in the negative.

The optimization work plan for LHAAP-18/24 will soon be submitted to the Army. It should be sent out to all stakeholders within a couple weeks.

Delivery of packages at Longhorn is an issue since the front gate is no longer manned and UPS/FedEx will not leave packages without a signature. At present, there are no package pickups and drop offs conducted at the installation. Paul Bruckwicki said they are looking into this and may work something out regarding drop off locations.

Status of Site Evaluation Report, LHAAP-06, -07, -51, -55, -64, -66, -68

Praveen Srivastav indicated there has been some discussion regarding the use of Risk Reduction Standard 2 versus Standard 3 based on previous conversations with stakeholders. At LHAAP-59, screening was initially done using: Standard 3 RBSVs and Standard 2 MSCs, however, RBSVs are meant for use only with Standard 3, so the RBSV step will be dropped for LHAAP-59 if the site is to be closed under Standard 2. For site LHAAP-59, the Army is considering Standard 2 as the best way to move forward. At LHAAP-59, Shaw will collect SPLP samples at or near the location where the maximum detection was found for chemicals above the ground water protection MSC (GWP).

Fay Duke stated that under Standard 2 a deed restriction and land use controls would be required if industrial MSCs are used. Rose Zeiler pointed out that deed restriction and LUCs will not be required for LHAAP-59 because of the installation's designation as a wildlife refuge. Industrial use is consistent with the RAFU – reasonably anticipated future use of the former installation. Under a no further action ROD, limited monitoring is allowed, so five-year reviews would be conducted to ensure continued industrial use. An installation-wide land use control document will contain maps of all land use control sites and 5-year review sites.

A question was raised by Praveen Srivastav regarding the use of Standard 2 MSCs to screen new data at sites that already have a risk assessment conducted under Standard 3. Fay Duke indicated that Standard 2 MSCs can be used to screen new data even though there is a risk assessment under Standard 3. (Note: Fay Duke further clarified via e-mail that TCEQ would like to see if additional data would increase the cumulative risk of the site, requiring risk calculations). Further, the Army can decide to close out individual sites under Standard 2 or 3 within the installation. The whole installation does not have to be under one standard or the other.

Praveen Srivastav also inquired regarding the use of Standard 3 MSC equations. The consistency memo is not clear as to when these MSCs should be calculated, after a risk assessment or Standard 3 MSCs can be calculated as an alternative to a risk assessment.

LHAAP-16: Proposal to shut down the extraction system to evaluate MNA as a remedy for the site. Amar Bumb of Shaw explained the modeling conducted for LHAAP-16 and the conservative approach used to come up with the modeling results. Fay Duke indicated that the well in LHAAP-16 closest to the creek (16WW12) may be monitored for GWTP effluent criteria. She said that since there is dilution in the creek, sampling the surface water does not suffice. By the time it is found in the creek, it may already have impacted the water quality of the creek and the state does not consider that an adequate measure. Amar indicated that the attenuation goes down between 16WW12 and the creek, about 90 feet, and that the capture zone of the extraction wells does not extend to the creek.

Jeff Armstrong discussed some early issues and the “why” the system was installed at LHAAP-16. He indicated that there was no order to run this extraction system and that it was put in place for a limited time to gather data for a treatability study. Rose Zeiler read from an Army letter to regulators in which Army agreed that the wells would be pumped until the RI/FS was in place.. The state believes that the extraction system is keeping the groundwater plume at bay and, therefore, has necessitated the continued operation of this extraction system.

Fay indicated that she would place priority on any additional information provided and would try to get comments back to Shaw by week's end. Shaw will provide historical data for samples from the creek, and data from adjacent wells as soon as possible. Fay said that to show that MNA is a final remedy; we have to show plume stability as well as the presence of other lines of evidence. Fay expressed that there is uncertainty in the model used to calculate MSCs protective of surface water because of calibration issues. Praveen Srivastav indicated that Y-direction calculations were performed for LHAAP-16, however, wells are not available in the proper location for calibration of the model. Shaw will inform Fay if review by Chuck Stone should proceed.

Fay also stated that PQL versus SQL for LHAAP-03, -06, -07, -51, and -55 should be corrected or explained. This will be clarified in the response to comment (RTC) as appropriate and the lab will be informed as to which rules should be followed.

Defense Environmental Restoration Program (DERP) TERC Update (Praveen Srivastav/John Elliott)

John Elliott discussed the highlights of the Document Status Table. He said that the RTC table for SI LHAAP-59 was submitted the day before. He indicated that a document would be submitted about once a week in the near future.

MQL versus SQL were also discussed. MSC can be replaced by MQL but not by SQL, if MQL is higher than MSC. These issues will be clarified in the RTC.

MMRP Update

John Lambert expects that a draft final of the EE/CA will go out by late April. There had been some issues regarding the comment responses that had to be dealt with. The Army expects comments from regulators in 30-45 days. Scott Harris thought that the review would go quicker than that and it is his priority.

Rose Zeiler read a signed letter from the Refuge Manager Mark Williams to Army regarding the Refuge's future plans for the Signal Test and Static Test Areas at LHAAP. In the letter it was stated that the Refuge would assist the Army with whatever controls it decides are necessary and that if the Army decides that the areas can be open to the public the Refuge will allow all of the "big six" public use activities that are compatible with the purpose and mission of the Refuge (hunting, fishing, wildlife observation, wildlife photography, wildlife education and wildlife interpretation). Additionally, it was stated that any restrictions on the implementation of the "big six" activities on the two sites would be coordinated with the Army prior to their establishment. It was also reiterated that the Army is ultimately responsible for the liability on these two areas.

Transfer Update

Electric Utilities. SWEPCO came out on March 14, 2007. They have installed a temporary primary meter at the Army's transformer that will allow USFWS to be billed for their power usage, thus paving the way for transfer of the Fire Station.

ECOP IV

The ECOPIV is ready and the public review period for ECOPIV is over. Rose Zeiler noted that a public review is not typically done for ECOPs but she has done it at Longhorn because of strong public interest. The Army is waiting on an approval letter from the EPA. Steve said that he expedited this and indicated it is in legal review. Raji Josiam checked the status and confirmed that a letter should be mailed out the next day. Rose Zeiler indicated that ECOPIV encompasses about 640 acres and that a total of 6954.4 acres would be transferred with 1,462 acres remaining. She expects the 50-acre LHAAP-12 Parcel to be transferred later this year, bringing the total transferred acreage to in excess of 7000. She said that it is down to the environmental sites now remaining and future parcel transfers will be small.

Pits and Hazards.

Rose Zeiler indicated the contractor was ready to move sometime this month. Although the issue regarding disposal of contaminated water found in some of the pits is still being addressed. The Army will be removing the physical hazards where possible, including rebar.

Refuge Opening

Paul Bruckwicki said that the Refuge is open only on a limited basis and that they are still providing guided tours. Paul indicated that visitors to the Refuge should not impact Shaw's activities and the environmental sites.

Demolition Landfill

Rose indicated that the landfill failed the inspection because of settling and some ruts.

Next monthly manager's meeting is scheduled for May 15, 2007 at 1:00 PM via teleconference. The June 2007 month managers' meeting coincides with the RAB meeting scheduled for June 12, 2007, at 3:00 PM (the time was later changed to 2:30 PM) with the RAB meeting following at 6:30.

Meeting Adjourned.

Action Items:

Army

- Forward MMRP report to EPA and TCEQ when available.

Shaw

- Provide additional information on LHAAP-16 to TCEQ.

EPA

- Steve Tzhone to determine if a proposed plan and public comment period is required with an NFA ROD that follows implementation of an Action Memorandum and EE/CA

that had already undergone public review – this question relates to the NTCRA at MMRP sites.

TCEQ

- Fay Duke will find out how Standard 3 MSC equations are to be used. Are they to be used to calculate clean up goals after a risk assessment or they can be used in lieu of a risk assessment?
- Fay Duke to respond to Shaw's request to use actual data for calculation of a dilution factor after reviewing data to be provided by Shaw

ATTENDEES

[illegible]

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USACE/Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
	ERA								
1	Draft Final Step 3 report (Vol I of BERA)	1/16/07		x	2/15/07		Under regulatory review	x	As discussed, report will be issued in two parts to expedite review. BERA (Volume 2) will follow later due to sampling analysis durations.
2	Draft BERA (Vol II of BERA)	1/31/07	x		2/16/07		Complete		
3	Draft Final BERA (Vol II of BERA)	3/6/07		x	4/6/07		Under regulatory review	x	
	ENVIRONMENTAL								
4	Draft Final SI/Evaluation Report, LHAAP-02	3/30/06		x			Comments rec'd from TCEQ 8/29/06. EPA comments rec'd 5/12/06.	x	Final will be issued when ERA information available.
5	Draft Final Proposed Plan, LHAAP-60	7/7/06		x			Comments rec'd from TCEQ 8/1/06. EPA comments rec'd 8/21/06.	x	Final to be submitted when ERA information available.
6	LHAAP-18/24 GWTP Sampling Optimization Memo	11/15/06		x	12/16/06		Complete	x	Informational workplan to be provided.
7	Draft Final TCRA Memo – LHAAP-04, -49, -50, and Pistol Range	12/6/06	x				Currently undergoing resolution between Army and Shaw.		
8	Perimeter Well Sampling Optimization Memo	12/28/07		x	1/27/07	Comments rec'd from EPA 1/22/07 and TCEQ 2/8/07 and agreed to.	Complete		

Status of Technical Documents – 4 week look ahead
Longhorn Army Ammunition Plant – PBC Contract
April 03, 2007

No.	Documents in Progress	Submittal Date	Army	Regulator	Comments Due from USA/CE/Regulators	Comment Resolution	Status	On Stakeholder's Portal?	Remarks
9	Draft Feasibility Study, LHAAP-58	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.
10	Draft Feasibility Study, LHAAP-17	TBD					On hold pending BERA		Draft versions 80% complete. Can not be finalized until eco issues resolved/ ERA further along.
11	Draft Feasibility Study, LHAAP-16	11/30/06	x		12/18/06 (Army)		Complete		
12	Draft Final Feasibility Study, LHAAP-16	TBD					On hold pending review of MNA evaluation proposal (see below)		
13	Draft Final SI Report for LHAAP-06, 07, -51, -55, -64, -66, -68 (combined)	1/11/07		x	2/10/07		In regulatory review. No comments rec'd.	x	
14	Draft SI Report for LHAAP-35/36	4/10/07 (Army)					In preparation		Report that summarizes sampling data for sumps
15	Quarterly GWTP Report	4/21/07 (Army)					Complete		1 st quarter 2007 report covering Jan - Mar
16	Draft LHAAP-16 MNA Evaluation Proposal	2/21/07 (Army)	x				Complete		
17	Draft Final LHAAP-16 MNA Evaluation Proposal	3/2/07		x	4/2/07	EPA comments rec'd 3/28/07, TCEQ comments pending.	In regulatory review	x	
18	Draft SI Report for LHAAP-03	4/17/07 (Army)					In preparation		Report that summarizes sampling data

Technical Document Status Table
TERC Task Order NO. 0109
Longhorn Army Ammunition Plant

00043557

No.	Site	Documents in Progress	Draft Document			Draft Final Document					Final Document Final Submittal Date					
			Draft Submittal Date	Army Comments	Shaw RTC	Comment Resolution	Draft Final Submittal Date	AEC Comments	EPA Comments	TCEQ Comments		Shaw RTC	Army Comments	Comment Resolution	Army forward RTC to TCEQ & EPA	Comment Resolution
1	LHAAP-12	Remedial Design Addendum, Rev 03, LHAAP-12	07/14/06	08/11/06			08/17/06	None Required	09/05/06	03/15/07	04/19/07					
2	LHAAP-12	Well Abandonment and Installation Report, LHAAP-12					06/07/06	None Required	07/17/06	09/27/06	10/19/06	10/31/06	11/07/06	11/20/06	TCEQ 03/06/07 EPA 03/06/07	04/12/07
3	LHAAP-12	Results of Modeling for Natural Attenuation of TCE, LHAAP-12					05/15/06	None Required	03/27/07	03/15/07	04/19/07	/19				
4	LHAAP-32	Proposed Plan, LHAAP-32					07/21/06	08/25/06	09/05/06	09/12/06	09/19/06			11/21/06	TCEQ 12/07/06 EPA 01/26/07	
5		Evaluation of Perimeter Well Data for use as Groundwater Background					03/07/06	None Required	04/19/06	10/24/06	11/07/06	RMZ 11/07/2006 USACE 11/20/06	11/20/06	11/21/06	TCEQ 12/07/06 EPA 02/21/07	04/25/07
6		Data Gaps Investigation Report					05/18/05	None Required	05/17/06	10/24/06	11/07/06	RMZ 11/09/2006 USACE 11/20/06	11/28/06	11/29/06	TCEQ 02/28/07 EPA 12/06/06	05/17/07
7	LHAAP-48/53	Site Evaluation Report, LHAAP-48/53					03/10/06	None Required	04/20/06	07/06/06	10/27/06	10/31/06	10/31/06	11/02/06	EPA concur 11/03/06 TCEQ comments 11/13/06	04/05/07
8	LHAAP-48/53	Revised Proposed Plan, LHAAP-48/53	09/25/06	10/31/06	11/14/06	01/12/07	04/05/07									
9	LHAAP-37/67	Proposed Plan, LHAAP-37/67	05/02/06	05/24/06	06/06/06	06/22/06	07/18/06	08/25/06	09/05/06	09/20/06	10/19/06	10/31/06	11/07/06	11/21/06	TCEQ 02/21/07	
10	LHAAP-37/67	Natural Attenuation Modeling Report, LHAAP-37/67	09/22/06	10/13/06	10/27/06	10/31/06	11/14/06		SCOTT	FAY						
11	LHAAP-08	Proposed Plan, LHAAP-08	05/01/06	05/24/06			07/07/06	08/25/06	08/21/06	09/20/06	09/29/06			11/21/06	TCEQ 12/07/06 EPA 02/21/07	
12	LHAAP-59	Site Investigation Report, LHAAP-59	11/02/06	11/07/06	11/09/06	11/15/06	11/21/06	None Required	03/20/07	01/11/2007, 03/20/07, & 03/22/07	04/02/07					
13	LHAAP-12/37/67	Natural Attenuation Evaluation, LHAAP-12/37/67	10/31/06	11/30/06	12/08/06	12/08/06	12/15/06	None Required	RAJI							
14	LHAAP-12/37/67	Memorandum regarding MNA Evaluation, LHAAP-12, 37, & 67	02/15/07	02/16/07	02/16/07	02/16/07	02/16/07		03/27/07							
Show Forecasted Submittal Date			Shaw Action Item			Army Action Item			EPA & TCEQ Action Item			Current Action item				

Current Action Item

EPA & TCEQ Action Item

Army Action Item

Shaw Action Item

Shaw Forecasted Submittal Date

LONGHORN ARMY AMMUNITION PLANT,

00043558

Karnack, Texas

MONTHLY MANAGERS' MEETING

AGENDA

DATE: Tuesday, 03 April 2007
TIME: TBD
PLACE: Shaw Office, Houston, TX

Welcome

RMZ

Review of March 2007 Meeting Minutes and Action Items

RMZ

Army

- Forward MMRP report to EPA and TCEQ when available.

Shaw

- Provide map and hotel information for IAP meeting in April, 2007.
- Send current schedule to EPA and TCEQ.

EPA

- Steve Tzhone to forward the MNA guidance when it becomes available.

Defense Environmental Restoration Program (DERP) PBC Update

DC/PS

- Document Status/Environmental Sites (Table)
- BERA update
- GWTP update
- LHAAP-16 – Extraction system shut down/MNA sampling proposal
- Status of Site Evaluation Report, LHAAP-6, 7, 51, 55, 64, 66, 68

DERP Total Environmental Restoration Contract Update

PS/JE

- Documents Status/Environmental Sites (Table)
- LHAAP-48/53 update
- LHAAP-12 update
- LHAAP-37/67 update

MMRP Update

CM

Transfer Update

RMZ

ECOP IV
Pits and Hazards Abatement
Refuge Opening
Demolition Landfill



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

April 9, 2007

DAIM-BD-LO

Mr. Steve Tzhone
US Environmental Protection Agency
Superfund Division (6SF-AT)
1445 Ross Avenue
Dallas, TX 75202-2733

Re: Final Site Evaluation Report LHAAP-48 (Y-Area) and LHAAP-35C(53) (Static Test Area), Longhorn Army Ammunition Plant, Karnack, Texas, April 2007

Dear Mr. Tzhone,

The above-referenced document is being transmitted to you for your files.

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

Sincerely,

A handwritten signature in black ink, reading "Rose M. Zeiler".

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

Copies furnished:
Fay Duke, TCEQ, Austin, TX
Paul Bruckwicki, Caddo Lake NWR, TX
Cliff Murray, COE – Tulsa District, OK
John R. Lambert, COE – Tulsa District, OK
P. Srivastav, Shaw – Houston, TX (for project files)



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

April 9, 2007

DAIM-BD-LO

Ms. Fay Duke
Texas Commission on Environmental Quality
TCEQ Environmental Cleanup Section II MC-221
12100 Park 35 Circle
Austin, TX 78753

Re: Draft Final Proposed Plan for LHAAP-48 (Y-Area) and LHAAP-35C(53) (Static Test Area), Longhorn Army Ammunition Plant, Karnack, Texas, April 2007

Dear Ms. Duke,

The above-referenced document is being transmitted to you for your review. Your comments are due on May 9, 2007.

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

Sincerely,

A handwritten signature in black ink, reading "Rose M. Zeiler", is positioned below the word "Sincerely,".

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

Copies furnished:
Stephen Tzhone, USEPA Region 6, Dallas, TX
Paul Bruckwicki, Caddo Lake NWR, TX
Cliff Murray, COE – Tulsa District, OK
John Lambert, COE – Tulsa District, OK
P. Srivastav, Shaw – Houston, TX (for project files)

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
TCEQ Review Comments						
1		Section 2.2	It is stated that chromium in unfiltered samples collected in 2005 from two wells (LHSMW 62 and 63) significantly exceeded its federal maximum contaminant level (MCL), and exceeded its MCL by 3.8 times in a filtered sample collected from one well (LHSMW 62). Additionally, it is suggested that elevated chromium groundwater levels are associated with suspended sediments and corrosion of the stainless steel well screen. As chromium was used in the manufacture of hand-held signals and illuminating projectiles, the TCEQ cannot concur with this conclusion without further study and data. Additionally, if the corrosion of the stainless steel well screen is suspected in contaminating the groundwater, it is imperative that corrective action be taken immediately.	D	<p>Chromium concentrations at LHAAP 48 have been evaluated previously. The question was addressed in the <i>Final Remedial Investigation Report, Vol. 1, for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50,60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas, January 2002</i>, prepared by the Jacobs Engineering Group, Inc.</p> <p>The Jacobs (2002) report characterized 50 soil samples and 10 groundwater samples for contamination associated with sumps and other potential sources and concluded (Section 10.5) that chromium was not found in soil near the sumps at LHAAP-48, and "... may have been a limited source of a variety of contamination. However, there is no widespread soil contamination or significantly organic-contaminated groundwater, which indicates that the sources are probably small and isolated and have not contributed to significant migration of contaminants."</p> <p>Regarding metals, the report found, "The low levels of metals contaminants in the Site 48 soils are mostly barium, cadmium, and lead.", and "The soil metals may migrate slowly via infiltrating precipitation. The low metals levels of these metals in groundwater suggest no significant leaching. However, the presence of elevated chromium levels in groundwater suggests an unidentified or no longer remaining source in the soils at Site 48."</p> <p>A later assessment was prepared by Plexus</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p>Scientific Corp. (Plexus) in 2005, <i>Final Environmental Site Assessment, Phase I and II Report, Production Areas, Longhorn Army Ammunition Plant, Karnack, Texas</i>. The purpose of the Plexus investigation was, in part, to address the potential sources near LHAAP-48.</p> <p>The Plexus report (Section 6.10) describes the LHAAP-48 (Area Y) buildings, which were used initially for production of illuminating devices. In later years the site was dedicated to preparation of black powder, and buildings and equipment were periodically washed as a safety measure to reduce accumulation of hazardous dusts. Because these washings were collected in some of the 12 Area Y waste sumps, it is reasonable to expect that LHAAP-48 contaminants identified in groundwater would be found in soil near the sumps also.</p> <p>The Plexus report included a building-by-building discussion of materials processed at Area Y activities. This discussion identifies Building 34-Y as the mixing area for pyrotechnic materials for hand signals, "... which consisted of various combinations of strontium nitrate, zirconium hydride, silicon, organic peroxides, polyester resins, barium nitrate, polyvinyl chloride, TNC [tetranitrocarbazole], cobalt, magnesium, and potassium perchlorate." The M583, M661 illuminants, Signal, Smoke, and Illumination Marine materials, MK 120 MOD O (Green) and MK 121 MOD O (Yellow), were prepared in Building 34-Y, as were Solvent Green #3 and Solvent Yellow #3 smoke powders. None of these illuminants included chromium compounds (see Table 4-3. <i>Chemical</i></p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p><i>Composition of Device Components</i>, Plexus, 2005).</p> <p>MK 120 MOD O (Green) and MK 121 MOD O (Yellow) were handled in Building 16-Y. Building 38-Y was used for consolidation of illuminants and black powder, as was Building 45-Y. Building 48-Y was used as a magazine for metal powders and green and yellow smoke compositions [MK 120 MOD O (Green) and MK 121 MOD O (Yellow)]. Buildings 38-Y, 45-Y, and 48-Y contain references to delay composition, which contains barium chromate.</p> <p>In summary, the results of Jacobs (2002) and Plexus (2005) evaluations indicate detections of barium, cadmium, and lead in soil, but chromium was not detected in soil. Chromium was detected in groundwater, but, because it was not detected in sumps or soils, the source the source was described (Jacobs, 2002) as "... unknown or no longer remaining in soils at Site 48."</p> <p>Data from analysis of groundwater from wells at LHAAP 48 and 35C(53) are shown in Table 2-1 and Table 3-1. All of the wells have 316 stainless steel screens except for Well 48WW01, Well 107, and the piezometer wells, which have polyvinyl chloride (PVC) screens. Well construction diagrams will be included in the revised report as Appendix E.</p> <p>The samples with chromium concentrations above the MCL are from stainless steel-screened wells only. All groundwater from PVC-screened wells contains</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p>undetected or low estimated (J-qualified) chromium and nickel concentrations, including the highly turbid samples from wells PZ002 and PZ004.</p> <p>The observations that chromium was not detected in soil associated with the expected source sumps, but elevated chromium concentrations were detected only in wells with stainless steel screens, suggest that the chromium is associated with corroded screens and represents the unknown source suggested in the Jacobs (2002) report.</p> <p>A meeting was held in Austin on August 11, 2006 to resolve regulatory comments on the Draft Final Site Evaluation Report. The meeting was attended by representatives from the Army, Shaw, EPA and TCEQ. It was agreed that, in an effort to achieve a final resolution regarding elevated chromium at certain wells, the Army would install and sample a new PVC well near LHSMW62. If this well does not contain elevated chromium, the chromium issue will be considered resolved and the Army will abandon all stainless steel wells at LHAAP-48 and 53.</p> <p>The new well 48WW02 was installed and sampled in September 2006. Chromium concentrations in samples from this well are shown in Table 2-2 of the revised report and the text has been revised as follows: "Of the metals detected in filtered samples, only chromium in water from monitoring well LHSMW62 exceeded the MCL of 100 µg/L (379 µg/L), approximately one-half of the concentration in the unfiltered sample (715 µg/L). The chromium concentration in filtered water from LHSMW63 was 60.7 (below the MCL) compared to the value in the</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

1. Respondent Concur (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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p>unfiltered sample of 2,510 µg/L as shown in Table 2-1.</p> <p>The source of chromium in groundwater from LHAAP-48 wells has been discussed previously. The Jacobs (2002) report characterized 50 soil samples and 10 groundwater samples for contamination associated with sumps and other potential sources and concluded in Section 10.5 that chromium was not found in soil near the sumps at LHAAP-48, and that the sumps "... may have been a limited source of a variety of contamination. However, there is no widespread soil contamination or significantly organic-contaminated groundwater, which indicates that the sources are probably small and isolated and have not contributed to significant migration of contaminants."</p> <p>Regarding metals, the report found, "The low levels of metals contaminants in the Site 48 soils are mostly barium, cadmium, and lead.", and "The soil metals may migrate slowly via infiltrating precipitation. The low metals levels of these metals in groundwater suggest no significant leaching. However, the presence of elevated chromium levels in groundwater suggests an unidentified or no longer remaining source in the soils at Site 48."</p> <p>The Plexus (2005) report (Section 6.10) describes the LHAAP-48 (Area Y) buildings, which were used initially for production of illuminating devices. In later years the site was dedicated to preparation of black powder, and buildings and equipment were periodically washed as a safety measure to reduce accumulation of hazardous dusts. Because these washings were collected in some of the 12 Area Y waste sumps, it is reasonable to expect that</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

1. Respondent Concur (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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p>LHAAP-48 contaminants identified in groundwater would be found in soil near the sumps also.</p> <p>The Plexus (2005) report identifies Building 34-Y as the mixing area for pyrotechnic materials for hand signals, colored smokes, and illuminant materials, although none of the materials handled in this building contained chromium compounds. The report references Buildings 16-Y, 38-Y, and 48-Y as locations where illuminants, colored smoke compositions were handled, and delay composition, which contains barium chromate.</p> <p>In summary, the results of Jacobs (2002) and Plexus (2005) evaluations indicate that chromium may have been handled in some LHAAP-48 buildings, and would be expected to be included in building washings diverted to sumps, but chromium was not detected in soil.</p> <p>Data from analysis of groundwater from wells at LHAAP 48 and 53(35C) are shown in Table 2-1 and Table 3-1. All of the wells have 316 stainless steel screens except for Well 48WW01, Well 107, and the piezometer wells, which have polyvinyl chloride (PVC) screens. Well construction diagrams are included in Appendix E. Groundwater samples with chromium concentrations above the MCL are from stainless steel-screened wells only. All groundwater from PVC-screened wells contains undetected or low estimated (J-qualified) chromium and nickel concentrations, including the highly turbid samples from wells PZ002 and PZ004.</p> <p>The observations that chromium was not detected in soil associated with the expected source sumps, and elevated chromium concentrations were detected only in wells with stainless steel screens, suggest that the chromium in groundwater is</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

1. Respondent Concur (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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					<p>associated with corroded screens and represents the unknown source suggested in the Jacobs (2002) report.</p> <p>To test this hypothesis, a new well with PVC casing material (48WW02) was installed near LHSMW62 and sampled in September 2006. Chromium concentrations in groundwater samples from this well (Table 2-2) indicate undetected or low estimated concentrations well below the MCL for chromium and well below the concentrations observed in well LHSMW62. These results support the hypothesis that chromium concentrations in groundwater from LHSMW62 originated from stainless steel casing used in that well (Table 2-1), and not from chromium in soil."</p> <p>The Army will proceed to abandon the wells as agreed once the revised report is accepted by regulators.</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
2		Section 3.2	It is reported that arsenic and chromium in unfiltered samples collected in 2005 from two wells (well 106 and LHSMW 71) exceeded their respective MCLs; antimony exceeded its MCL in a filtered sample from one well (LHSMW 67); antimony, arsenic, and lead exceeded their respective MCLs in unfiltered piezometer samples (PZ002 and PZ004); and arsenic and lead exceeded their respective MCLs in a filtered piezometer sample (e.g., arsenic was 3 times the MCL in PZ004). Section 3.2 suggests that chromium is not a site-related Chemical of Potential Concerns (COPC) and that elevated chromium groundwater levels are associated with corrosion of the stainless steel well screen. Please see above comments regarding the chromium issue. Additionally, we are concerned that some filtered samples still contained levels of contaminants other than chromium (i.e., arsenic, lead, antimony) greater than their respective MCLs.	D	<p>See response to Comment 1 for discussions of previous studies. The static test area was used in the manufacture of explosives, assembly of CS rounds, testing of pyrotechnics and to test fire rocket engines. Four waste sumps are located at this site. Isolated contamination was detected in soil and groundwater; however, the constituents are not the same (Section 6.14, Plexus, 2005). Soil contained beryllium, cadmium, lead, selenium and silver; groundwater contained aluminum, chromium, iron, nickel, silver, and thallium. As indicated by groundwater concentrations, the metals detected in soil are unlikely to affect the underlying groundwater (Jacobs, 2002; Plexus, 2005). The Plexus (2005) report indicates that elevated chromium and nickel concentrations usually are associated with elevated iron concentrations, such as those that occur at this site (Plexus, 2005).</p> <p>The Jacobs (2002) report describes elevated chromium concentrations in groundwater from well LHSMW71, which is not accompanied by a source in soil, and the report suggested the possibility of an, as yet, undetected source.</p> <p>Well LHSMW71 is located southeast of Building 23-T, which is an HMX manufacturing building described in Section 6.11 of the Plexus (2005) report. Four soil borings and temporary monitoring wells (1010SB/TW001 through 1010SB/TW004) were installed surrounding Building 23-T to investigate possible sources of chromium contamination. No metals were detected in groundwater from these wells (Section 6.11.4,</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
				C	<p>Plexus, 2005). Because these additional wells failed to confirm another source of chromium in soil or groundwater associated with Building 23-T soil at LHAAP-53(35C), these results support the hypothesis that the source of elevated chromium concentrations in groundwater at LHSMW71 is the well material itself.</p> <p>See response to Comment 1 regarding further resolution of chromium issue.</p> <p>The site evaluation report will be revised to include the above information and to clarify the conclusion that corroded stainless steel screens are the source of chromium.</p> <p>Well 106 is 1,600 to 2,000 feet downgradient from both LHAAP-48 and LHAAP-53(35C) sites, and is not a source of groundwater contamination for either site. Potential impacts of arsenic chromium concentrations above MCL levels in groundwater at Well 106 probably reflect turbid samples and are not likely to affect surface water quality at Caddo Lake, the most immediate downgradient receptor. Well 106 is located in an area that has been transferred to the USFWS. References to Well 106 were removed from the revised report.</p> <p>Antimony does not exceed the MCL in any filtered sample except at well LHSMW67, but it was not detected in the unfiltered sample. This result is anomalous and possibly results from misidentified filtered and unfiltered samples.</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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 No.	Page	Section/ Paragraph	Comment	C, D ¹ , E or X	Response	A or D ²
					Arsenic and lead do not exceed MCL concentrations in any filtered sample except samples from piezometer wells PZ004. These concentrations are not detected in nearby wells completed in the same groundwater bearing unit (107, LHSMW70, or LHSMW71). Arsenic and lead are not identified as a chemical of potential concern in soil samples associated with sumps that are known to have received waste from site operations. It is likely that the samples from these piezometer wells reflect the condition of the temporary wells that were designed to provide groundwater gauging or screening level information and not confirmatory groundwater analytical data.	
3		Appendix C and D	TCEQ staff of the Toxicology Section (TS) reviewed the Draft Final Site Evaluation Report to ensure compliance with Standard No. 3 of the 1993 Risk Reduction Rule (RRR) and the July 23 rd , 1998 memorandum entitled, "Implementation of the Existing Risk Reduction Rule," hereafter referred to as the Consistency Document (available on the internet at http://www.tceq.state.tx.us/remediation/rrr.html). More specifically and as requested, TS's review focused on portions of the DFSER dealing with human health risks and hazards associated with potential residential exposure to site-related contaminants in soil and groundwater (i.e., Appendices C and D).	C	See responses to specific comments below.	

Appendix C: Baseline Risk Assessment for Residential Use of LHAAP-48

4		2.4 Evaluation of Dioxins and Furans	This section indicates that a 2,3,7,8-TCDD toxicity equivalency quotient (TEQ) was calculated based on the sample results and toxicity equivalency factors (TEFs) for the individual dioxin/furan congeners. However, supporting calculations were not provided. Additionally, please provide	C	The comment seems to refer to the 2003 Jacobs Engineering Group, Inc. risk assessment cited in the draft document as Jacobs, 2003.	
---	--	--------------------------------------	---	---	--	--

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

			clarification as to the reason that the value of soil source term concentration for 2,3,7,8-TCDD is different in this report as those value used in the 2002 risk assessment report.		<p>The 2003 risk assessment for dioxins is based on 7 samples (48SB01, SUMP094, SUMP095, SUMP098, SUMP100, WRSUMP001, and WRSUMP003).</p> <p>The assessment included calculation of the 2,3,7,8-TCDD TEQ concentration in each depth interval using toxicity equivalent factors (TEF) given in Section 3.2.4. Details of the calculation are not shown, but the calculations were limited to samples from the 0–0.5 depth from the 6 sumps (SUMP094, SUMP095, SUMP098, SUMP100, WRSUMP001, and WRSUMP003) and 1 soil boring (48SB01) (see Table 3-26 of the 2003 document). The maximum 2,3,7,8-TCDD TEQ concentration (1.58E-05 mg/kg at SUMP094 was used as the exposure point concentration for all exposures to dioxins in the LHAAP-48 risk assessments (Table 3-95, Jacobs, 2003).</p> <p>The TCEQ has determined that it is appropriate to assess the applicable soil column to a depth that is reasonably likely to be encountered as a result of excavation activities which could bring contaminated materials to the surface. For a residential land-use scenario, this surface soil extends from ground surface to 15 feet in depth or to the top of the groundwater-bearing unit, whichever is less in depth (TCEQ Consistency Memorandum, 1998).</p> <p>Therefore, Shaw has calculated 2,3,7,8-TCDD TEQ values using the same method and TEF values and soil concentrations used in the Jacobs (2003) risk assessment, but included 15 samples collected from the upper 5 feet of the soil column (the deepest samples taken). The maximum 2,3,7,8-</p>	
--	--	--	--	--	---	--

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

					TCDD TEQ concentration calculated for the 15 samples differs slightly from the value used in the 2003 risk assessment, but the the difference in values does not affect the conclusions of the LHAAP-48 risk assessment. The detailed 2,3,7,8-TCDD TEQ calculations have been included in the revised final report as Section 2.4	
5		2.5 Identification of Chemicals of Potential Concern	This section indicates that risk-based screening values (RBSVs) for soil are also protective of groundwater. Although TS does not evaluate groundwater protection, the RBSVs for most chemicals of potential concern (COPCs) are not considered protective of residential groundwater. For example, the RBSVs for chromium VI (20 mg/kg) and chromium III (5,900 mg/kg) are higher than the residential soil groundwater protection value (10 mg/kg).	C	Agree. The sentence "The RBSVs for soil are also protective of groundwater (TCEQ, 2004)." will be deleted in the revised document.	
6		2.5.2 Organic Chemicals in Soil	This section indicates that four polycyclic aromatic hydrocarbons (PAHs) were eliminated as COPCs since they were not considered associated with site operations. The TCEQ does not agree. We believe it is appropriate to include PAHs (i.e., benzo(a)anthracene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene) in the list of COPCs. The maximum soil concentrations of benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene exceed their respective Standard 2 residential soil medium-specific concentrations (MSCs). Additionally, the 95 percent upper confidence limit (95% UCL) calculated for benzo(b)fluoranthene exceeds its residential soil MSC, and the 95% UCLs calculated for benzo(a)anthracene and indeno(1,2,3-cd)pyrene (which are below their respective residential soil MSCs) are likely calculated over an exposure area larger than that considered acceptable for risk assessments under the RRR (see comments below on Section 3.3).	D	The Army believes that the PAH compounds are associated with asphalt residues from paving at the sites, which is not expected to be removed prior to transfer of the property to the USFWS. It was agreed during the August 11, 2006 meeting in Austin that PAHs will be excluded from the risk assessment, as described in paragraph 3 of the revised Appendix C.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

7	3.1 Land and Water Uses	<p>This section indicates that surface water runoff from the northern portion enters an <i>Unnamed Creek</i> to the south, and runoff from the southern portion enters <i>Central Creek</i> to the southeast and on to <i>Caddo Lake</i>, but that no major surface water bodies exist at the site. Additionally, shallow groundwater flow is to the southeast toward <i>Central Creek</i>. Therefore, surface water protection shall be evaluated to ensure no contaminants above health base levels enters the surface water bodies.</p>	C	<p>Potential risks associated with migration of shallow groundwater from LHAAP-48 and surface water runoff are not overlooked at LHAAP.</p> <p>The LHAAP-48 site is located within Section 1009 at LHAAP. The Plexus (2005) report states, "No surface water bodies were visible on Section 1009. Numerous manmade drainage ditches were observed in the production area. No standing water was observed in the drainage ways at the time of the site reconnaissance."</p> <p>Transport by surface water runoff and discharge of shallow groundwater to the above surface water bodies is evaluated in a separate report entitled, <i>Final Modeling Report, Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army ammunition Plant, Karnack, Texas, September 2006</i>.</p> <p>Paragraph 2 of Section 3.1 of the risk assessment was revised to read," The perimeter of LHAAP-48 is a mixture of heavily wooded areas and grasslands. The topography slopes gently to the southeast, and surface runoff from the northern part of the site enters an unnamed rainwater drainage ditch to the south. Numerous manmade drainage ditches were observed in the production area (Plexus, 2005) but no standing water was observed in the drainage ways at that time. Runoff from the southern portion of LHAAP-48 eventually enters Central Creek to the southeast and on to Caddo Lake. Transport by surface water runoff and discharge of shallow groundwater to other surface water bodies is evaluated in a separate report (Shaw, 2006)."</p>	
---	-------------------------	--	---	--	--

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

8		3.2 Site Conceptual Model	This section indicates that residential exposure to COPCs in fish was not assessed as site surface water does not support a fish population. However, if Texas Surface Water Quality Standards (TSWQS) are determined to be applicable to surface water at the site, it is TS's understanding that TSWQS consider at least incidental fish ingestion regardless of whether a fish population is actually present. More stringent TSWQS apply to sustainable fisheries and surface water which is a source of drinking water as determined under TSWQS.	C	<p>The most stringent TSWQS apply to Caddo Lake, a drinking water source, which is considered in earlier risk assessments.</p> <p>The revised report will state that because the intermittent unnamed creek at LHAAP-48 is in reality a rainwater ditch, it does not support a fish population, and a potential resident would have ready access to fish from Caddo Lake, potential risk from ingestion of fish from the unnamed creek will be considered negligible and not evaluated in the risk assessment.</p> <p>The third bullet in the second paragraph of Section 3.2 of Appendix C was revised to read, "Exposure of the resident to COPCs in fish is not assessed. Because the ephemeral unnamed creek at LHAAP-48 is in reality a rainwater ditch (Section 3.1), it does not support a fish population, and a potential resident would have ready access to fish from Caddo Lake. or one of the other watersheds, potential risk from ingestion of fish from the unnamed creek would represent the trespasser scenario evaluated in previous risk assessments (Jacobs, 2002, 2003). Therefore, the potential ingestion of fish from this ditch is not evaluated in this risk assessment."</p>	
9		3.3 Determination of Source-Term Concentrations	The acreage of the areas used to calculate 95% UCLs is not indicated. However, as the site is approximately 16 acres (see Section 3.1) and soil samples were collected across the site (see Figure C-1), it appears that 95% UCLs were calculated over an area larger than the default exposure areas considered acceptable for risk assessments under the RRR. Please note that per Section IV.3.1.1 of the Consistency Document, the exposure area for a residential scenario should be assumed to be 1/8 acre for undeveloped	C	<p>The report has been revised to include the maximum concentrations of COPCs as the reasonable maximum exposure (RME) for residential risk assessment.</p> <p>The TCEQ (1998) guidance specifies an exposure area of 1/8 acre for use in residential risk assessments. There is a probability that a</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

			property. Alternatively, a party may be able to demonstrate that a larger exposure area is appropriate based on <i>documented</i> and <i>verifiable</i> information for future residential development (e.g., zoning requirements). Use of maximum detected concentrations as exposure point concentrations would satisfy TS concerns regarding calculating 95% UCLs over exposure areas exceeding those considered acceptable for risk assessments under the RRR.		hypothetical resident could locate a 1/8 acre site at the locations sampled, and incur an exposure to COPCs higher than other locations at LHAAP-48. Therefore, the use of the maximum COPC concentrations to represent the exposure point concentration at any LHAAP-48 location represents the RME approach for this assessment, as consistent with EPA (1989) and TCEQ (1998) guidance.	
10		Table C-2	This table appears to eliminate benzo(a)pyrene, dibenzo(a,h)anthracene, and vinyl chloride as COPCs based on frequency of detection alone (see footnote "d" to Table C-2), which is inconsistent with the Consistency Document. This appears to be a misunderstanding of Section III.1 of the Consistency Document, which indicates that a COPC may be eliminated from further consideration in the BLRA if it meets <i>all</i> the following criteria: (1) it is detected in less than 5% of at least 20 samples; (2) it is only detected in one media; (3) its maximum concentration (i.e., the higher of the maximum detected concentration or the appropriate proxy value for non-detects per Section II.4.3) is less than its Standard 2 MSC; and (4) there is no reason to believe it is present at the site. However, the maximum levels for benzo(a)pyrene, dibenzo(a,h)anthracene, and vinyl chloride exceed their respective Standard 2 residential soil MSCs, so criterion (3) above is not met.	C	See response to Comment 6 regarding the PAH compounds benzo(a)pyrene, dibenzo(a,h)anthracene. Vinyl chloride was included in the revised risk assessment and evaluated at the maximum concentration, as described in Sections 3.2 through 3.4 of the revised Appendix C.	
11		Table C-3	Please use an age-adjusted dermal factor of 352 mg-yr/kg-event. Additionally, an adult exposure duration of 30 years may be used.	C	Comment refers to Table C-5 of the revised Appendix C. The age-adjusted dermal factor was changed to 352 mg-yr/kg-event, and the adult exposure duration of 30 years, were used in the revised risk assessment, although they are not specified in the Consistency Document cited in comment 3.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

12		Table C-5	A reference dose (RfD) of 0.2 mg/kg-day may be used for barium.	C	The RfD of 0.2 mg/kg-day was used for barium in Table C-6 of the revised risk assessment.	
13		Table C-9a	The cumulative cancer risk presented in this table is 2E-07. The risk calculated from the incidental ingestion of 2,3,7,8-TCDD in soil alone is 2.19E-06. Therefore, the cumulative risk total of 2E-07 (which is less than 2.19E-06) is incorrect.	C	This error was corrected in Table 10a of the revised risk assessment.	

Appendix D: Baseline Risk Assessment for Residential Use of LHAAP-35C(53)

14		2.4 Evaluation of Dioxins and Furans	This section indicates that a 2,3,7,8-TCDD toxicity equivalency quotient (TEQ) was calculated based on the sample results and toxicity equivalency factors (TEFs) for the individual dioxin/furan congeners. However, supporting calculations were not provided. Additionally, please provide clarification as to the reason that the value of soil source term concentration for 2,3,7,8-TCDD is different in this report as those value used in the 2002 risk assessment report.	C	See response to comment 4. Shaw has calculated 2,3,7,8-TCDD TEQ values for 5 samples collected from the upper 5 feet of the soil column. The maximum 2,3,7,8-TCDD TEQ concentration calculated for the 5 samples differs slightly from the value used in the 2003 risk assessment, but the difference in values does not affect the conclusions of the LHAAP-53/35(C) risk assessment. The detailed 2,3,7,8-TCDD TEQ calculations are included in Section 2.4 of the revised final Appendix D.	
15		2.5 Identification of Chemicals of Potential Concern	This section indicates that RBSVs for soil are also protective of groundwater. Although TS does not evaluate groundwater protection, the RBSVs for most COPCs are not considered protective of residential groundwater.	C	Agree. The sentence "The RBSVs for soil are also protective of groundwater (TCEQ, 2004)." will be deleted in the revised document.	
16		3.1 Land and Water Uses	This section indicates that surface water runoff is towards <i>Central Creek</i> and <i>Harrison Bayou</i> . Surface water protection should be evaluated.	C	See responses to comment 7.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

17		3.2 Site Conceptual Model	This section indicates that residential exposure to COPCs in fish were not assessed as site surface water sources do not support a fish population. However, if TSWQS are determined to be applicable to surface water at the site, it is TS's understanding that TSWQS consider at least incidental fish ingestion regardless of whether a fish population is actually present. More stringent TSWQS apply to sustainable fisheries and surface water which is a source of drinking water as determined under TSWQS.	C	See responses to comment 8. The second bullet of Paragraph 2 of Section 3.2 has been revised to read, "Exposure of the resident to dioxins in fish is not assessed. Because available surface water sources at LHAAP-35C(53) do not support a fish population, and a potential resident would have ready access to fish from Caddo Lake, or one of the other watersheds, potential risk from ingestion of fish from the unnamed creek would represent the trespasser scenario evaluated in previous risk assessments (Jacobs, 2002, 2003). Therefore, the potential ingestion of fish from this ditch is not evaluated in this risk assessment."	
18		Table D-2	This table appears to eliminate benzo(a)pyrene and mercury as COPCs based on frequency of detection alone (see footnote "d" to Table D-2), which is inconsistent with the Consistency Document. This appears to be a misunderstanding of Section III.1 of the Consistency Document, which indicates that a COPC may be eliminated from further consideration in the BLRA if it meets <i>all</i> the following criteria: (1) it is detected in less than 5% of at least 20 samples; (2) it is only detected in one media; (3) its maximum concentration (i.e., the higher of the maximum detected concentration or the appropriate proxy value for non-detects per Section II.4.3) is less than its Standard 2 MSC; and (4) there is no reason to believe it is present at the site. However, the maximum levels for benzo(a)pyrene and mercury exceed their respective residential soil MSCs, so criterion (3) above is not met.	C	See response to Comment 6 regarding the PAH compound benzo(a)pyrene.. Mercury was included in the revised risk assessment and evaluated at the maximum concentration, as described in Sections 3.2 through 3.4 of the revised Appendix D.	
19		Table D-3	Please use an age-adjusted dermal factor of 352 mg-yr/kg-event. An adult exposure duration of 30 years may also be used.	C	The age-adjusted dermal factor was changed to 352 mg-yr/kg-event, and the adult exposure duration of 30 years, were used in the revised risk assessment in Table D-4, although they are not specified in the Consistency Document cited in comment 3.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

EPA Review Comments

1	Pg. 2-5	Section 2.2	One duplicate value was reported as J-qualified (234.41 pg/L) and the other was reported as U-qualified (50.505 pg/L). Was unable to find the U-Qualified value of 50.505 pg/L	C	The interpretation of uncertainties associated with dioxin and furan data has been revised in paragraph 5 of Section 2.2 of the revised report was revised to read, "Filtered samples collected in May 2005 contained concentrations of dioxin or furan congeners ranging from 0.82 pg/L (intermediate monitoring well 48WW01) to 234.41 pg/L, which is a J-qualified concentration of octachlorodibenzo-p-dioxin measured in shallow monitoring well LHSMW64. Because the toxicity equivalency factor (TEF) value of octachlorodibenzo-p-dioxin is 0.0001 (Van den Berg, 1998), the octachlorodibenzo-p-dioxin contribution to the 2,3,7,8-TCDD TEQ concentration would be 0.0234, which is an insignificant contributor to the derived TEQ concentration and well below the MCL for 2,3,7,8-TCDD (30 pg/L). Therefore, the uncertainty associated with the range of dioxin and furan concentrations does not influence the interpretation of the groundwater data for dioxins/furans."	
2			Elevated chromium concentrations in wells LHSMW62 and LHSMW63 appears to be associated with suspended sediments, and its source is suspected to be the stainless steel screen of the wells. The increase in chromium concentrations was attributed to corrosion of the stainless steel screen, which was accompanied by increases in iron and aluminum concentrations (Table 2-1). Increased chromium levels were detected in wells LHSMW62 and LHSMW63 due to the Stainless Steel screens. Why were they not seen in other wells? Also, the high levels of chromium seen unfiltered samples do not correlate with the filtered samples. For example, the highest chromium level for the unfiltered sample was for LHSMW63 (2510.0). However, the highest chromium level	C	Samples with chromium concentrations above the MCL (100 µg/L) are from stainless steel-screened wells only (LHSMW62, LHSMW63, and LHSMW71). Other wells with stainless steel screens contained groundwater with detectable levels below the MCL ranging from 13.6 µg/L in well LHSMW68 to 66.80 µg/L in well LHSMW66. Water from other wells with stainless steel casings did not contain detectable chromium. These results indicate that corrosion is more advanced in wells LHSMW62, LHSMW63, and LHSMW71 than the other wells. It is reasonable to expect a correlation between chromium concentrations in water from stainless steel	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

			for the filtered sample was for LHSMW62 (379.0). Why is this the case?		<p>screened wells before and after filtration. The percentage of chromium concentration removed by filtration ranges from 47% at LHSMW62 to 98% at LHSMW71.</p> <p>It is also reasonable to expect that the groundwater samples contained variable amounts of undissolved solids. A stronger correlation would be expected between the reduction of chromium concentration and the amount of solids removed by filtration. However, the mass of solids collected on the filter is not recorded in the analytical methods used.</p> <p>Section 2.2 of the report was revised to clarify the role of stainless steel casing on groundwater as described above in responses to TCEQ comment 1.</p>	
Toxicology Section Review received by email on January 22, 2007						
			<p>Staff of the Toxicology Section (TS) have reviewed the US Army Corps of Engineers' responses to TS comments of August 9, 2006 on the <i>Draft Final Site Evaluation Report LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53) (Former Static Test Area)</i> for the Longhorn Army Ammunition Plant (LHAAP) located in Karnack, Texas. The responses were provided in a November 2, 2006 e-mail to the TCEQ project manager. Previous TS comments were provided to the TCEQ project manager in an August 9, 2006 interoffice memorandum. TS reviewed the responses to ensure compliance with Standard No. 3 of the 1993 Risk Reduction Rule (RRR) and the July 23rd, 1998 memorandum entitled, "Implementation of the Existing Risk Reduction Rule," hereafter referred to as the Consistency Document (available at www.tceq.state.tx.us/remediation/rrr.html). TS only reviewed responses to previous TS comments concerning issues which were not deferred to the TCEQ project manager. Previous TS comments concerning issues not deferred to</p>			

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

			the TCEQ project manager appear in <i>italics</i> below and are followed by comments on the US Army Corps of Engineers' responses. Issues deferred to the TCEQ project manager are not addressed (e.g., surface water protection and applicability of TSWQS to various waterbodies, whether PAHs in soil and chromium in some groundwater wells are site related).			
1		Appendix C, Section 2.4 Evaluation of Dioxins and Furans	<p><i>This section indicates that a 2,3,7,8-TCDD toxicity equivalency quotient (TEQ) was calculated based on the sample results and toxicity equivalency factors (TEFs) for the individual dioxin/furan congeners. However, supporting calculations were not provided.</i></p> <p><i>Comment: The response to this comment indicates that the US Army Corps of Engineers concurs with the comment (as denoted by "C" in the fifth column of their response table for comment no. 4). However, the response does not provide supporting TEQ calculations or indicate that supporting calculations are forthcoming.</i></p> <p>Comment: In response, supporting TEQ calculations were provided in Table 1, which adequately addressed TS's concern.</p>		These calculations are provided in revised Appendix C.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

2		Appendix C, Section 3.3 Determination of Source-Term Concentrations	<p><i>TS did not evaluate the bootstrap method used to calculate 95% UCLs on the mean COPC concentrations. The acreage of the areas used to calculate 95% UCLs is not indicated. However, as the site is approximately 16 acres (see Section 3.1) and soil samples were collected across the site (see Figure C-1), it appears that 95% UCLs were calculated over an area larger than the default exposure areas considered acceptable for risk assessments under the RRR. Please note that per Section IV.3.1.1 of the Consistency Document, the exposure area for a residential scenario should be assumed to be 1/8 acre for undeveloped property. Alternatively, a party may be able to demonstrate that a larger exposure area is appropriate based on documented and verifiable information for future residential development (e.g., zoning requirements). Use of maximum detected concentrations as exposure point concentrations would satisfy TS concerns regarding calculating 95% UCLs over exposure areas exceeding those considered acceptable for risk assessments under the RRR.</i></p> <p><i>Comment: The response (comment no. 9 in the response table) will adequately address TS's concern if the risk assessment is revised per the response.</i></p> <p>Comment: TS has not yet received a revised BLRA which incorporates maximum concentrations (per the response) to address this concern. TS notes that the response provided for comment no. 9 has been revised since August 2006 to indicate that the residential scenario assumes excavation and mixing of the soil within the upper 5 feet. TS disagrees. Surface soil for the residential scenario is from 0-15 feet and does not assume mixing. In fact, unless</p>		<p><u>Shaw Response:</u> The first sentence of the response states, "The report will be revised to include the maximum concentrations of COPCs as the reasonable maximum exposure (RME) for residential risk assessment." This approach is consistent with the baseline risk assessment methodology described in the TCEQ Risk Reduction Rules under Risk Reduction Standard 3. The application of Risk Reduction Standard 3 guidance to LHAAP is consistent with baseline risk assessments conducted using commercial/industrial land use assessments in 2002 and 2003. The above mention of surface soil as represented by 0 to 5 feet is a typographical error. The correct reference to surface soil for a residential risk assessment is correctly made in Shaw's response to TCEQ's original comment number 4. The surface and subsurface soil will be aggregated and statistical methods will be applied as described in Section IV.3.2.3 of the Consistency Document if a most likely exposure (MLE) estimate is made in the revised Appendix C, April 2007.</p>	
---	--	---	---	--	--	--

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

			the contamination is demonstrated to be relatively homogeneous over a maximum of the top 2 feet, statistics (e.g., 95% UCLs) should not be used to dilute higher concentrations which may be present at the surface with lower concentrations at greater depths. Please see Section IV.3.2.3 of the Consistency Document for more information on appropriately aggregating data by depth.			
3		Appendix C, Table C-2	<p><i>This table appears to eliminate benzo(a)pyrene, dibenzo(a,h)anthracene, and vinyl chloride as COPCs based on frequency of detection alone (see footnote "d" to Table C-2), which is inconsistent with the Consistency Document. This appears to be a misunderstanding of Section III.1 of the Consistency Document, which indicates that a COPC may be eliminated from further consideration in the BLRA if it meets all the following criteria: (1) it is detected in less than 5% of at least 20 samples; (2) it is only detected in one media; (3) its maximum concentration (i.e., the higher of the maximum detected concentration or the appropriate proxy value for non-detects per Section II.4.3) is less than its Standard 2 MSC; and (4) there is no reason to believe it is present at the site. However, the maximum levels for benzo(a)pyrene, dibenzo(a,h)anthracene, and vinyl chloride exceed their respective Standard 2 residential soil MSCs, so criterion (3) above is not met.</i></p> <p><i>Comment: The response (comment no. 10 in the response table) will adequately address TS's concern if the risk assessment is revised to</i></p>		<p><u>Shaw Response:</u> See response to TCEQ comment 6 regarding the PAH compounds benzo(a)pyrene and dibenzo(a,h)anthracene. Vinyl chloride will be included in the revised Appendix C, April 2007.</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

			<p><i>include these COCs per the response.</i></p> <p>Comment: The determination as to whether PAHs are site related was deferred to the TCEQ project manager. In regards to vinyl chloride, the above comment has not yet been addressed.</p>			
4		Appendix C, Table C-3	<p><i>Please use an age-adjusted dermal factor of 352 mg-yr/kg-event. Additionally, an adult exposure duration of 30 years may be used.</i></p> <p><i>Comment: The response (comment no. 11 in the response table) will adequately address TS's concern if the risk assessment is revised per the response.</i></p> <p>Comment: TS has not yet received a revised BLRA with the above-referenced changes (per the response) to address this comment.</p>		<p><u>Shaw Response:</u> The response to the original TCEQ comment states, "The age-adjusted dermal factor will be changed to 352 mg-yr/kg-event and the adult exposure duration of 30 years will be used in the revised Appendix C, April 2007..."</p>	
5		Appendix C, Table C-9a	<p><i>The cumulative cancer risk presented in this table is 2E-07. The risk calculated from the incidental ingestion of 2,3,7,8-TCDD in soil alone is 2.19E-06. Therefore, the cumulative risk total of 2E-07 (which is less than 2.19E-06) is incorrect.</i></p> <p><i>Comment: The response (comment no. 13 in the response table) will adequately address TS's concern if the risk assessment is revised per the response.</i></p> <p>Comment: TS has not yet received a revised BLRA which incorporates risk from dioxin into the cumulative assessment (per the response) to address this concern.</p>		<p><u>Shaw Response:</u> The response to the original TCEQ comment states, "This error will be corrected in the revised Appendix C, April 2007."</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

6		Appendix D, Section 2.4 Evaluation of Dioxins and Furans	<p><i>This section indicates that a 2,3,7,8-TCDD toxicity equivalency quotient (TEQ) was calculated based on the sample results and toxicity equivalency factors (TEFs) for the individual dioxin/furan congeners. However, supporting calculations were not provided.</i></p> <p><i>Comment: The response to this comment indicates that the US Army Corps of Engineers concurs with the comment (as denoted by "C" in the fifth column of their response table for comment no. 14). However, the response does not provide supporting TEQ calculations or indicate that supporting calculations are forthcoming.</i></p> <p>Comment: In response, supporting TEQ calculations were provided in Table 2, which adequately addressed TS's concern.</p>		These calculations are provided in revised Appendix D.	
7		Appendix D, Table D-2	<p><i>This table appears to eliminate benzo(a)pyrene and mercury as COPCs based on frequency of detection alone (see footnote "d" to Table D-2), which is inconsistent with the Consistency Document. This appears to be a misunderstanding of Section III.1 of the Consistency Document, which indicates that a COPC may be eliminated from further consideration in the BLRA if it meets all the following criteria: (1) it is detected in less than 5% of at least 20 samples; (2) it is only detected in one media; (3) its maximum concentration (i.e., the higher of the maximum detected concentration or the appropriate proxy value for non-detects per Section II.4.3) is less than its Standard 2 MSC; and (4) there is no reason to believe it is present at the site. However, the maximum levels for benzo(a)pyrene and mercury exceed their respective residential soil MSCs, so criterion (3) above is not met.</i></p> <p><i>Comment: The response (comment no. 18 in the</i></p>		Shaw Response: See response to TCEQ comment 6 regarding benzo(a)pyrene. Mercury will be included in the revised Appendix D, April 2007.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

			<p><i>response table) will adequately address TS's concern if the risk assessment is revised to include these COCs per the response.</i></p> <p>Comment: The determination as to whether PAHs are site related was deferred to the TCEQ project manager. In regards to mercury, the above comment has not yet been addressed.</p>			
8		Appendix D, Table D-3	<p><i>Please use an age-adjusted dermal factor of 352 mg-yr/kg-event. An adult exposure duration of 30 years may also be used.</i></p> <p><i>Comment: The response (comment no. 19 in the response table) will adequately address TS's concern if the risk assessment is revised per the response.</i></p> <p>Comment: TS has not yet received a revised BLRA with the above-referenced changes (per the response) to address this comment.</p>		<p><u>Shaw Response:</u> The response to the original TCEQ comment states, "The age-adjusted dermal factor will be changed to 352 mg-yr/kg-event and the adult exposure duration of 30 years will be used in the revised Appendix D, April 2007 ..."</p>	
Toxicology Section Question received by email on February 23, 2007						
1		Appendix D	<p>Please also ask how they treated nondetects in calculating the mean for Hg for LHAAP-35(C).</p>		<p>For nondetected (U-qualified) values, ½ of the MQL was substituted as a proxy value in statistical calculations. In the case of mercury, the low frequency of detection (1 detection among 32 samples analyzed) precludes use of this calculated mean as a representative concentration over the site. Therefore, neither the calculated mean, nor any other statistically derived value for mercury, was used in the risk assessment, and does not influence risk assessment conclusions.</p> <p>The maximum mercury concentration was chosen</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

					as the Source Term Concentration (see Table D-3) and was used as the basis of the revised Appendix D, April 2007. The use of the maximum concentration for all chemicals in the risk assessment is consistent with earlier TCEQ comments dated July 6, 2006.																									
TCEQ Questions on the Appendix D Risk Assessment for LHAAP-35C(53) from a conference call on February 28, 2007																														
1			Question regarding the effect of pH on the risk assessment for mercury		<p>The maximum mercury concentration was compared to the mercury MSC for soil given in current TCEQ Risk Reduction Rules tables. The tables indicate that the MSC (1.1E-01 mg/kg) is pH-dependent, and the tabulated value is based on pH 4.9, representing relatively acidic conditions.</p> <p>The pH-dependence of the soil-water partition coefficient (Kd) is described in TRRP guidance [Figure: 30 TAC §350.73(e)(1)(C)]. (Use of physical/chemical properties given in TRRP guidance for assessments conducted under the Risk Reduction Rule is consistent with TCEQ policy). Information from the TRRP figure shows the following Kd values for soil pH:</p> <table><tr><td>Soil pH</td><td>Mercury Kd</td><td>Mercury Soil MSC (mg/kg) *</td></tr><tr><td>4.9</td><td>4.0E-02</td><td>1.1E-01</td></tr><tr><td>5.0</td><td>6.0E-02</td><td>1.5E-01</td></tr><tr><td>5.1</td><td>9.0E-02</td><td>2.1E-01</td></tr><tr><td>5.2</td><td>1.4E-01</td><td>2.9E-01</td></tr><tr><td>5.3</td><td>2.0E-01</td><td>3.6E-01</td></tr><tr><td>5.4</td><td>3.0E-01</td><td>4.7E-01</td></tr><tr><td>5.5</td><td>4.6E-01</td><td>6.1E-01</td></tr></table> <p>* MSC calculated for residential land use using TCEQ equations and default parameters given in the Consistency Memorandum.</p> <p>Boldface type indicates values shown in the TCEQ Consistency Memorandum</p>	Soil pH	Mercury Kd	Mercury Soil MSC (mg/kg) *	4.9	4.0E-02	1.1E-01	5.0	6.0E-02	1.5E-01	5.1	9.0E-02	2.1E-01	5.2	1.4E-01	2.9E-01	5.3	2.0E-01	3.6E-01	5.4	3.0E-01	4.7E-01	5.5	4.6E-01	6.1E-01	
Soil pH	Mercury Kd	Mercury Soil MSC (mg/kg) *																												
4.9	4.0E-02	1.1E-01																												
5.0	6.0E-02	1.5E-01																												
5.1	9.0E-02	2.1E-01																												
5.2	1.4E-01	2.9E-01																												
5.3	2.0E-01	3.6E-01																												
5.4	3.0E-01	4.7E-01																												
5.5	4.6E-01	6.1E-01																												

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

					<p>The above table includes Soil MSC values that were calculated for each Kd value using the equations, default exposure values, and toxicity values given in the TCEQ Consistency Memorandum. The table shows that Kd and MSC values for mercury increase with increasing pH, but are relatively insensitive to pH in the acidic range.</p> <p>The pH of soil was not measured in samples collected at LHAAP-35(C)53. However, pH data are available for local soil from the background area, and from LHAAP-49, which was an acid storage area.</p> <p>Soil pH in Background Area</p> <table><tr><th colspan="5">Standard</th></tr><tr><th><u>Mean</u></th><th><u>Deviation</u></th><th><u>Median</u></th><th><u>Minimum</u></th><th><u>Maximum</u></th></tr><tr><td>5.20</td><td>0.39</td><td>5.20</td><td>4.40</td><td>6.5</td></tr></table> <p>Soil pH at LHAAP-49</p> <table><tr><th colspan="5">Standard</th></tr><tr><th><u>Mean</u></th><th><u>Deviation</u></th><th><u>Median</u></th><th><u>Minimum</u></th><th><u>Maximum</u></th></tr><tr><td>5.72</td><td>0.86</td><td>5.63</td><td>4.26</td><td>7.09</td></tr></table> <p>This pH information shows that soil in the background area is somewhat more acidic than soil at LHAAP-49 as indicated by the mean and median values, although there is considerable overlap in the pH ranges. Therefore, pH data for the background soil would lead to more conservative MSC values for screening of mercury concentrations at LHAAP-53.</p> <p>Mercury was detected in only 1 of 32 samples collected at LHAAP-35(C)53, representing a</p>	Standard					<u>Mean</u>	<u>Deviation</u>	<u>Median</u>	<u>Minimum</u>	<u>Maximum</u>	5.20	0.39	5.20	4.40	6.5	Standard					<u>Mean</u>	<u>Deviation</u>	<u>Median</u>	<u>Minimum</u>	<u>Maximum</u>	5.72	0.86	5.63	4.26	7.09	
Standard																																				
<u>Mean</u>	<u>Deviation</u>	<u>Median</u>	<u>Minimum</u>	<u>Maximum</u>																																
5.20	0.39	5.20	4.40	6.5																																
Standard																																				
<u>Mean</u>	<u>Deviation</u>	<u>Median</u>	<u>Minimum</u>	<u>Maximum</u>																																
5.72	0.86	5.63	4.26	7.09																																

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

					<p>frequency of detection of less than 5%. However, screening of chemicals based on frequency of detection is not allowed according to the TCEQ Consistency Memorandum if the maximum detected concentration exceeds the MSC value for the chemical. Because no soil pH data are available for LHAAP-35(C)53 soil, and the maximum mercury concentration (2.4E-01 mg/kg) exceeds the MSC provided in current TCEQ tables (1.1E-01 mg/kg at pH 4.9), mercury was retained in the risk assessment.</p> <p>If the mean or median pH for background soil were assumed for LHAAP-35(C)53, mercury would be screened from the risk assessment according to TCEQ criteria by comparison of the maximum concentration at (2.4E-01 mg/kg) to the calculated residential MSC (2.9E-01 mg/kg). The observation of pH values below 4.9 in both background and LHAAP-49 soil would confirm our decision to retain mercury in the risk assessment, and pH values above pH 5.2 would remove mercury from the risk assessment. Either result would not change the conclusion of the risk assessment, nor provide it more support.</p>	
2			Question regarding the assessment of mercury inhalation		<p>The draft risk assessment evaluated the inhalation pathway for mercury in airborne dust suspended from soil. The calculated hazard quotient (HQ) was 1.66E-07, below the acceptable level of 1. This approach is consistent with assessment of ionic forms of mercury as implied by use of pH-dependent K_d values.</p> <p>If the conservative assumption is made that the mercury is in the more volatile metallic form, inhalation of mercury vapor would be included in the assessment. The calculated HQ would be 2.6E-01,</p>	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

					still below the acceptable value of 1. The assumption that mercury is present at the maximum concentration in the more volatile form over the entire site results in an assessment that conservatively overestimates the HQ. Because the resulting HQ is still less than 1, the assumption does not change the risk assessment conclusions.	
Toxicology Section Question received by email on March 6, 2007						
			This memorandum contains a revised section on <i>Appendix D: Baseline Risk Assessment for Residential Use of LHAAP-35C(53)</i> as compared to the TS memorandum dated February 27, 2007. The revisions are in response to additional information supplied on March 1, 2007. Staff of the Toxicology Section have reviewed the US Army Corps of Engineers' responses to TS comments of November 10, 2006 on the <i>Draft Final Site Evaluation Report LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53) (Former Static Test Area)</i> for the Longhorn Army Ammunition Plant (LHAAP) located in Karnack, Texas. Previous TS comments on the baseline risk assessments (BLRAs) for LHAAP-48 (Appendix C) and LHAAP-35C(53) (Appendix D) were provided to the TCEQ project manager in an August 9, 2006 interoffice memorandum. TS reviewed responses and revised sections of the BLRAs to ensure compliance with Standard No. 3 of the 1993 Risk Reduction Rule (RRR) and the July 23 rd , 1998 memorandum entitled, "Implementation of the Existing Risk Reduction Rule," hereafter referred to as the Consistency Document (available at www.tceq.state.tx.us/remediation/rrr.html). Issues previously deferred to the TCEQ project manager are not addressed (e.g., surface water protection and applicability of TSWQS to various waterbodies, whether PAHs in soil and chromium in some groundwater wells are site related). For this memorandum, TS concentrated on sections of the BLRAs which were the subject of comments			

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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

			in the November 10, 2006 TS memorandum and BLRA conclusions.			
1		Appendix C, Section 5.3 Risks Associated with Exposure to Soil	The last paragraph of this section draws the conclusion of acceptable risk/hazard for soil constituents at LHAAP-48 based solely upon cumulative risk and hazard considerations. However, the RRR also has target individual-chemical risk (1E-06 for class A and B carcinogens, 1E-05 otherwise) and hazard (HQ of 1) levels. Based on the risks presented in Table C-10a, which were calculated using maximum concentrations, the excess cancer risk calculated for vinyl chloride from exposure to soil (i.e., $1.16\text{E-}06$ (soil ingestion) + $5.64\text{E-}05$ (inhalation) = $5.76\text{E-}05$) exceeds the RRR individual-chemical target risk for class A carcinogens (1E-06). However, based on the surface soil sample results provided in Table C-3, vinyl chloride was detected in only 1 of 48 samples, and the reporting limits for the other 47 samples were adequate (i.e., below the SAI-Res MSC). Therefore, for most of the site it appears that vinyl chloride would not represent unacceptable risk under the RRR. The one detect is approximately 14 times the residential cleanup value. The site appears too large and the nondetects too numerous to appropriately use the other available sample results in a statistical calculation (95% UCL) of an exposure concentration (i.e., the exposure area would be very large), and the one detected high sample result would likely cause the 95% UCL to exceed the cleanup value anyway. <i>TS defers to the TCEQ project manager in regards to what actions, if any, are necessary to address vinyl chloride in the area of the one sample where it was detected.</i>		Because the risk assessments described in Appendices C and D are based on maximum detected concentrations, no 95% UCL was used. A Section 7.0 (Risk Management) was added to the main document to describe risk management decisions based on the risk assessment results and Risk Reduction Standard 3 requirements.	

**Comments on Draft Final Site Evaluation Report
LHAAP-48 (Former Igniter Production Area) and LHAAP-35C(53)(Former Static Test Area)
Longhorn Army Ammunition Plant Dated March 2006**

August 2006 through March 2007

TCEQ Reviewer: Team 2, Environmental Cleanup Section II, Fay Duke, Project Manager, Texas Commission on Environmental Quality

USEPA Reviewer: Raji Josiam, Remedial Project Manager, USEPA Region 6

Respondents: Arthur F. Eidson, Praveen Srivastav, Shaw E & I

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.

2		Appendix D, Section 5.3 Risks Associated with Exposure to Soil and Table D-7b	<p>The last paragraph of Section 5.3 draws risk/hazard conclusions for soil constituents at LHAAP-35C(53) based solely upon cumulative risk and hazard considerations. Discussions of acceptable risk and hazard in future BLRAs should include not only RRR target cumulative risk (1E-04) and hazard (HI of 1) levels, but RRR target individual-chemical risk (1E-06 for class A and B carcinogens, 1E-05 otherwise) and hazard (HQ of 1) levels as well.</p> <p>The inhalation hazard presented in Table D-7b for mercury in soil is less conservative than TS's calculation because although mercury is a volatile metal (see the vapor pressure in the RRR chemical/physical parameter table), the volatilization factor (VF) for mercury was not considered in the BLRA. Available data indicate that the mean pH for soils in this area may be in the range of 5.2-5.7 (mean). <i>If the TCEQ project manager determines that these pH results are likely representative of site conditions, even if the VF is considered, it appears that mercury is unlikely to represent an unacceptable hazard at this site and could have been screened from the BLRA.</i></p>		<p>See response to the above comment 1 regarding the discussion of risk management in Section 7.0 of the revised report.</p> <p>See response to TCEQ comment 3 of February 28, 2007 comments regarding the mercury inhalation evaluation.</p>	

FINAL
SITE EVALUATION REPORT
LHAAP-48 (FORMER IGNITER PRODUCTION AREA)
AND LHAAP-35C(53) (FORMER STATIC TEST AREA)
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



Prepared for
U.S. Army Corps of Engineers
Tulsa District
1645 South 101st Avenue
Tulsa, Oklahoma

Prepared by
Shaw Environmental, Inc.
3010 Briarpark
Houston, Texas 77042

TERC No. DACA56-94-D-0020, Project No. 845714
Task Order No. 0109

April 2007

Table of Contents

List of Tables	ii
List of Figures	ii
List of Appendices	ii
Acronyms and Abbreviations	iii
1.0 Introduction	1-1
1.1 LHAAP Description and History	1-1
1.2 LHAAP-48 Description and History	1-3
1.2.1 Previous Investigations	1-3
1.2.2 Industrial Risk Assessment at LHAAP-48	1-3
1.3 LHAAP-35C(53) Description and History	1-4
1.3.1 Previous Investigations	1-4
1.3.2 Industrial Risk Assessment at LHAAP-35C(53)	1-4
1.4 Rationale for Additional Groundwater Sampling in 2004 and 2005	1-4
2.0 LHAAP-48 Groundwater Sampling in 2004 and 2005	2-1
2.1 Groundwater Sampling and Analytical Methods	2-1
2.2 Summary of Analytical Results	2-3
3.0 LHAAP-35C(53) Groundwater Sampling in 2004 and 2005	3-1
3.1 Groundwater Sampling and Analytical Methods	3-1
3.2 Summary of Analytical Results	3-2
4.0 Summary of the Residential Risk Assessment for Hypothetical Residential Use	4-1
4.1 Elements of the Residential Risk Assessment	4-1
4.2 Results of the Residential Risk Assessment	4-1
5.0 Conclusions	5-1
6.0 Risk Management	6-1
7.0 References	7-1

List of Tables

Table 2-1	Groundwater Sampling Results from May 2005, LHAAP-48
Table 2-2	Groundwater Sampling Results from Well Installed Near LHSMW62, LHAAP-48
Table 3-1	Groundwater Sampling Results from May 2005, LHAAP-35C(53)
Table 6-1a	Cancer Risk from Exposure to Chemicals in Soil at LHAAP-48 and LHAAP-35C(53)
Table 6-1b	Noncancer Hazard from Exposure to Chemicals in Soil at LHAAP-48 and LHAAP-35C(53)

List of Figures

Figure 1-1	LHAAP Location Map
Figure 2-1	LHAAP-48 and LHAAP-35C(53) Monitoring Well Location Map

List of Appendices

Appendix A	Groundwater Sampling Forms LHAAP-48
Appendix B	Groundwater Sampling Forms LHAAP-35C(53)
Appendix C	Baseline Risk Assessment for Residential Use of LHAAP-48
Appendix D	Baseline Risk Assessment for Residential Use of LHAAP-35C(53)
Appendix E	Construction Diagrams for Groundwater Wells at LHAAP-48 and LHAAP-35C(53)

Acronyms and Abbreviations

BHHRA	baseline human health risk assessment
DCA	dichloroethane
HI	hazard index
LHAAP	Longhorn Army Ammunition Plant
LUC	land use controls
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
NTU	nephelometric turbidity units
µg/L	micrograms per liter
pg/L	picograms per liter
PVC	polyvinyl chloride
Shaw	Shaw Environmental, Inc.
TAL	target analyte list
TCE	trichloroethylene
TCEQ	Texas Commission on Environmental Quality
TEF	toxicity equivalency factor
TERC	Total Environmental Restoration Contract
TNT	trinitrotoluene
TO	Task Order
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1.0 Introduction

This site evaluation, prepared by Shaw Environmental, Inc. (Shaw) for the U.S. Army Corps of Engineers (USACE), Tulsa District, under Total Environmental Restoration Contract (TERC) DACA56-94-D-0020, Task Order (TO) No. 0109, presents a baseline risk assessment for residential use of LHAAP-48 and LHAAP-35C(53) based on existing information and the results of groundwater sampling activities at LHAAP-48 and LHAAP-35C(53) conducted by Shaw in 2004 and 2005.

Longhorn Army Ammunition Plant (LHAAP) is a former Army installation that occupied nearly 8,500 acres between State Highway 43, in Karnack, Texas, and the southwestern shore of Caddo Lake, as shown on **Figure 1-1**, LHAAP Location Map. The nearest cities are Marshall, Texas, approximately 14 miles to the southwest, and Shreveport, Louisiana, approximately 40 miles to the southeast. Caddo Lake, a large freshwater lake situated on the Texas-Louisiana border, bounds LHAAP to the north and east.

This site evaluation is presented in several sections and appendices. **Section 1.0** consists of site descriptions, a summary of previous investigations and the industrial risk assessment at sites LHAAP-48 and LHAAP-35C(53), and the rationales for additional groundwater sampling conducted by Shaw in 2004 and 2005. **Section 2.0** presents a summary of the results from the 2004 and 2005 groundwater sampling at LHAAP-48. **Section 3.0** presents a summary of the results from the 2004 and 2005 groundwater sampling at LHAAP-35C(53). **Section 4.0** summarizes the results of the baseline risk assessment for hypothetical residential use of LHAAP-48 and LHAAP-35C(53), incorporating the results of groundwater sampling. The residential risk assessments are presented in their entirety in **Appendix C** and **D**. **Section 5.0** presents conclusions for residential risk at LHAAP-48 and LHAAP-35C(53). **Section 6.0** discusses risk management associated with total cancer risk estimates. **Section 7.0** is a list of references.

1.1 LHAAP Description and History

LHAAP was established in December 1941, near the beginning of World War II, when the Army issued a contract to build a six-line production facility for manufacturing trinitrotoluene (TNT). LHAAP ultimately produced 414 million pounds of TNT before production was halted in August 1945, near the end of the war, and the facility (Plant 1) went on standby status. In 1952, during the Korean War, the government reactivated and refitted Plant 2 for pyrotechnics production and Plant 3 was designed and built for producing solid-fuel rocket motors for tactical missiles. Actual rocket motor production began in December 1954; and the last major propellant loading activity in Plant 3 occurred in 1980.

00043597

DRAWING NUMBER 845714-A4

APPROVED BY K. EVERETT 03/20/06

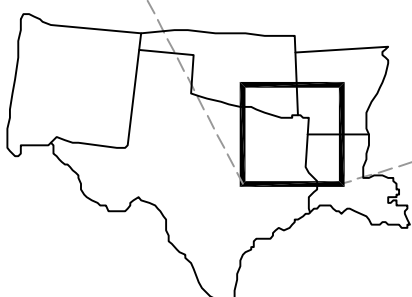
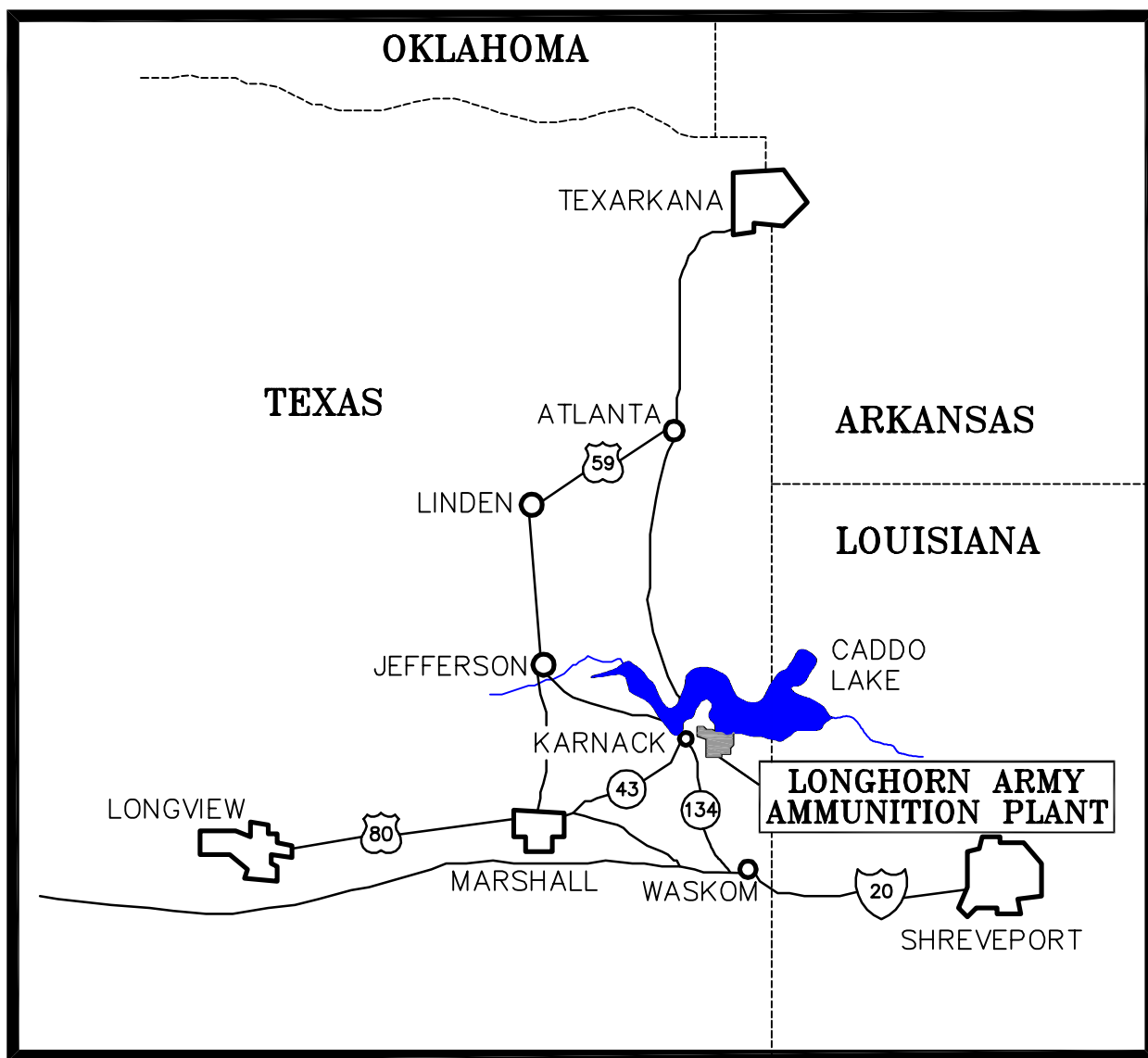
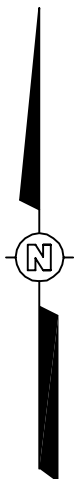
CHECKED BY F. EIDSON 03/20/06

DRAWN BY J. RDZ 12/17/03

OFFICE Houston, Texas

X-REF ---

IMAGE ---
PLOT DATE: 03/20/06
FORMAT REVISION 3/25/99



"DRAWING NOT TO SCALE"



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

FIGURE 1-1
LHAAP LOCATION MAP
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

1.2 LHAAP-48 Description and History

LHAAP-48, known as the former igniter production area or “Y-Area,” covers an area of approximately 16 acres, and was built during the construction of Plant 3, from 1953 through 1955. It was used for the production of igniters and illumination devices and was active until about 1997 (Jacobs Engineering Group, Inc. [Jacobs], 2003). There were nine waste process sumps and three waste rack sumps associated with this area. Environmental sampling was conducted to evaluate the nature and extent of contamination adjacent to the sump locations.

1.2.1 Previous Investigations

Previous investigations were conducted by Jacobs and others from 1982 through 2000 (Jacobs, 2002a, 2002b) culminating in the *Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunder’s Branch, Central Creek, and Caddo Lake, Longhorn Army Ammunition Plant, Karnack, Texas, June, 2003*, which is summarized in **Sections 1.2.2** below.

Jacobs calculated the noncancer hazard indices (HIs) and cancer risks for current trespassers and future industrial worker. Hazards and risks under the reasonable maximum exposure calculations are considered acceptable if the HI is less than 1.0 and the cancer risk is between 1×10^{-6} and 1×10^{-4} (U.S. Environmental Protection Agency [USEPA], 1994).

1.2.2 Industrial Risk Assessment at LHAAP-48

The BHHRA by Jacobs (2003) indicated acceptable cancer risk and non-cancer hazard from the soil at LHAAP-48. The calculated risk was 1.4×10^{-5} , within the acceptable range, and the HI was 0.88, which is less than 1. However, the cancer and non-cancer hazard risk were unacceptable for groundwater.

Groundwater ingestion accounted for over 99 percent of the groundwater noncancer hazard, generating an HI of 36 which is above the benchmark of 1. Thallium generated an HI of 25 and accounted for approximately 69 percent of the HI. 2,3,7,8-TCDD (1.2×10^{-4}) accounted for approximately 95 percent of the total groundwater cancer risk. Tetrachloroethene (1.8×10^{-6}) and TCE (1.7×10^{-6}) generated cancer risk in excess of 1×10^{-6} and accounted for approximately 3 percent of the cancer risk (Jacobs; 2002b, 2003). Therefore, the cancer risk and the noncancer HI for groundwater were unacceptable.

In addition to the risk contributors mentioned above, TCE [9 micrograms per liter ($\mu\text{g/L}$) at location LHSMW63] and bis(2-ethylhexyl) phthalate [7.7 $\mu\text{g/L}$ at location LHSMW66] exceeded the MCL values of 5 $\mu\text{g/L}$ and 6 $\mu\text{g/L}$, respectively. Antimony [51J $\mu\text{g/L}$ at location LHSMW63], arsenic [12 $\mu\text{g/L}$ at location LHSMW64], chromium [54,000 $\mu\text{g/L}$ at location LHSMW63], and thallium [205 $\mu\text{g/L}$ at location LHSMW64] exceeded the MCLs of 6, 10, 100, and 2 $\mu\text{g/L}$, respectively (Jacobs, 2002a).

1.3 *LHAAP-35C(53) Description and History*

LHAAP-35C(53) was the former static test area that was used for testing of illumination devices and static test firing of rocket motors. Structures for this site included a test tunnel and a data acquisition system for flares, rocket motor test stands of earth and concrete and conditioning facilities for reproducing arctic and tropical temperatures. The site was active through 1998. Four waste process sumps were associated with this area (Jacobs 2002a).

1.3.1 *Previous Investigations*

Previous investigations were conducted by Jacobs and others from 1982 through 2000 (Jacobs, 2002a) culminating in a BHHRA which is summarized in **Section 1.3.2** below.

1.3.2 *Industrial Risk Assessment at LHAAP-35C(53)*

The BHHRA by Jacobs (2003) indicated that the soil cancer risk was acceptable with an estimated value of 1×10^{-5} and the HI was acceptable at 0.05 for the future maintenance worker. The groundwater had a cancer risk estimated at 8×10^{-5} , within the acceptable range, and an HI of 22, which is above the acceptable benchmark of 1. Thallium primarily accounted for the unacceptable HI (Jacobs; 2002b, 2003).

In addition to the risk contributors mentioned above, 1,2-dichloroethane (DCA) [8 µg/L at location LHSMW67] and trichloroethylene (TCE) [7µg/L at location LHSMW67] exceeded MCLs of 5 µg/L in groundwater. Arsenic [16 µg/L at location LHSMW69], chromium [43,000 µg/L at location LHSMW71], and thallium (134 µg/L) exceeded the MCL of 10, 100, and 2 µg/L, respectively (Jacobs, 2002a).

1.4 *Rationale for Additional Groundwater Sampling in 2004 and 2005*

Previous investigations and the industrial risk assessment (Jacobs 2002a, 2002b, 2003) indicate that metals (i.e., thallium) and dioxins are primarily responsible for causing unacceptable cancer risk or noncancer hazard to the future maintenance worker at LHAAP-48 and LHAAP-35C(53). Other chemicals, such as chromium, antimony, TCE, and 1,2-DCA, exceeded their respective maximum contaminant levels (MCLs), though they were not major risk contributors. Experience at other sites has shown that some of these chemicals (e.g., metals and dioxins) can be elevated by high turbidity of the samples.

Because of the uncertainty of previous results, Shaw resampled the wells at LHAAP-48 and LHAAP-35C(53) using low-flow sampling methods in September 2004 and May 2005. Low-flow methods typically yield high-quality samples with low turbidity.

In September 2004, three monitoring wells at LHAAP-48 were sampled for dioxins/furans, perchlorate, and thallium, and seven monitoring wells at LHAAP-35C(53) were sampled for volatile organic compounds (VOCs) and perchlorate. Perchlorate was included for analysis

because of recent interest in this chemical and the potential for its presence at LHAAP-48 and LHAAP-35C(53). The results are presented in the *Draft Final Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas* (Shaw, 2005).

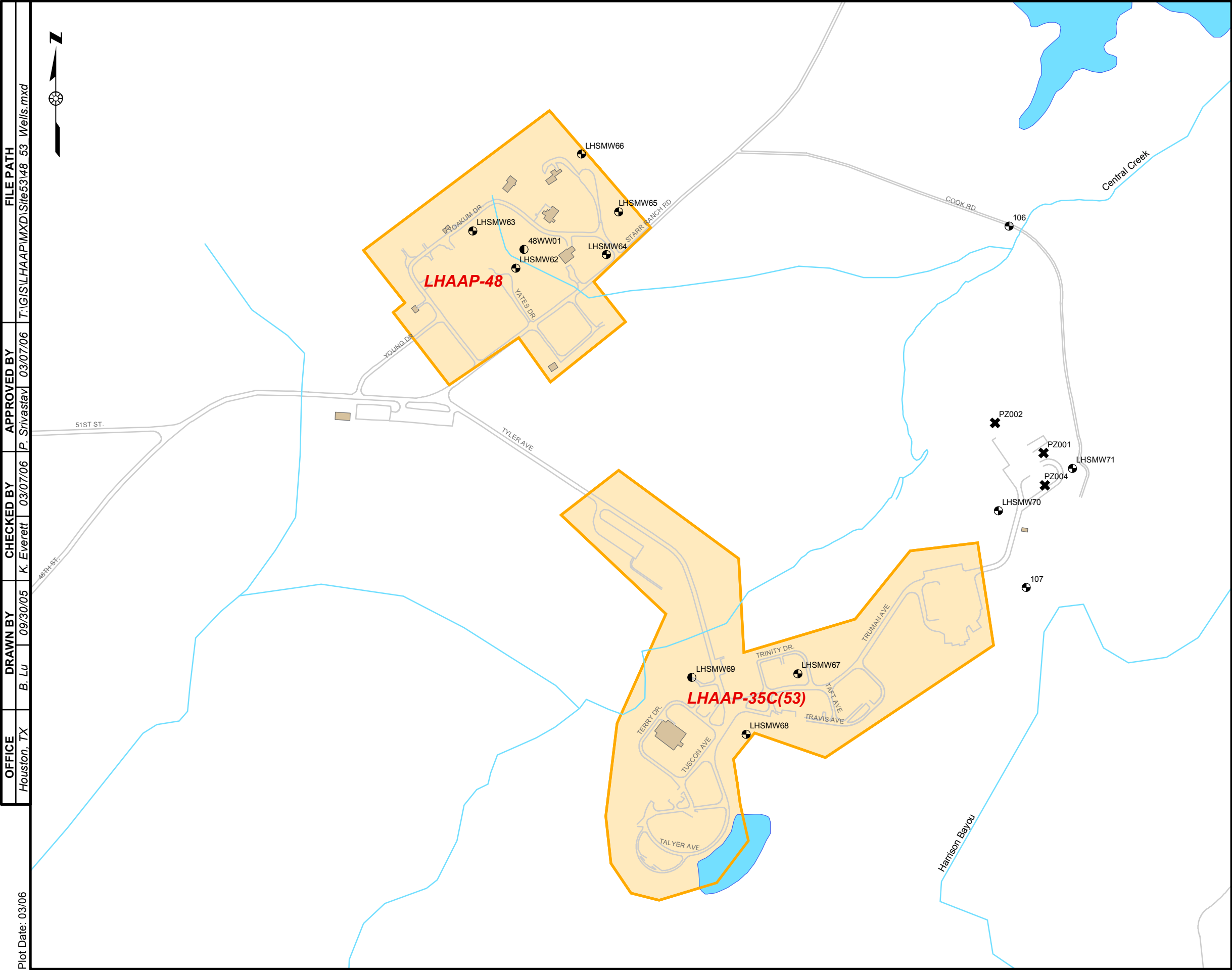
In May 2005, five monitoring wells were sampled for dioxins/furans, VOCs, perchlorate, and metals at LHAAP-48. Seven monitoring wells, including three temporary wells (piezometers), were sampled for dioxins/furans, metals, VOCs, and perchlorate at LHAAP-35C(53). The results are presented in **Tables 2-1** and **3-1** of this document.

2.0 *LHAAP-48 Groundwater Sampling in 2004 and 2005*

Monitoring well 48WW01 was installed as an intermediate-depth well in 2004 (**Figure 2-1**). An attempt to sample all six groundwater monitoring wells (48WW01, LSHMW62, LSHMW63, LSHMW64, LSHMW65, and LSHMW66) at the site was made in September 2004. Due to insufficient recharge conditions, groundwater samples could only be collected from 48WW01, LSHMW62, and LSHMW64. The samples were analyzed for dioxins/furans, perchlorate, and thallium, and showed elevated concentrations of dioxins and thallium. Although the turbidity of groundwater samples was quite low (10 to 20 nephelometric turbidity units [NTU] measured using a water-quality meter during sampling), it was suspected that elevated dioxin and thallium detections were related to the turbidity of the samples. Since the samples were not analyzed for aluminum and iron, these data were not available to evaluate the influence of turbidity on the sample results (Shaw, 2005). Therefore, additional sampling was conducted in May 2005 to collect and analyze filtered and unfiltered samples for metals and dioxins/furans from wells 48WW01, LSHMW62, LSHMW63, LSHMW64, LSHMW65, and LSHMW66. Samples collected from monitoring wells 48WW01, LSHMW62, and LSHMW64 were analyzed for VOCs, metals, dioxins/furans, and perchlorate. Because of insufficient monitoring well recharge rates, a sample could not be obtained from LSHMW65, and limited analyses were performed on the available amount of groundwater collected from LSHMW63 and LSHMW66. Groundwater samples from LSHMW63 were analyzed for VOCs and metals; and samples from LSHMW-66 were analyzed for VOCs, metals, and perchlorate. Results of the May 2005 sampling and analysis effort are discussed below.

2.1 *Groundwater Sampling and Analytical Methods*

In May 2005, Shaw sampled one intermediate and four shallow groundwater monitoring wells at LHAAP-48 (48WW01, LSHMW62, LSHMW63, LSHMW64, and LSHMW66). The wells were gauged for water levels and the well bottom depths were verified. Low-flow sampling methods were employed on 48WW01, using a downhole bladder pump and disposable tubing. Because of insufficient recharge, peristaltic pumps were used to purge and sample monitoring wells LSHMW62, LSHMW63, LSHMW64, and LSHMW66. Using a water-quality meter with a flow-through cell, water quality measurements were recorded that included turbidity, dissolved oxygen, pH, conductivity, temperature, and oxidation reduction potential. Groundwater samples were collected after stable readings indicated that appropriate water quality objectives had been met according to the site-specific standard operating procedures (Shaw, 2004). Monitoring wells LSHMW63 and LSHMW66 were purged dry prior to sampling because of a low recharge rate, and samples could not be obtained. Sampling activities were completed on May 16, 2005. Copies of the groundwater sampling forms are included as **Appendix A**.

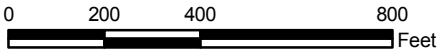


OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Lu	K. Everett	P. Sivastav	T:\GIS\LHAAP\MXD\Site53\48_53_Wells.mxd

Plot Date: 03/06

Legend

- Shallow Monitoring Well
- Intermediate Monitoring Well
- Piezometer
- Stream
- Road
- Former Building
- Water Body
- Site



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

FIGURE 2-1

LHAAP-48 AND LHAAP-35C(53)
MONITORING WELL LOCATION MAP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Filtered (filter size 0.45 microns) and unfiltered groundwater samples were analyzed for dioxins/furans and target analyte list (TAL) metals using USEPA SW-846 Methods 8290 and 6010B, respectively. Samples were also analyzed for mercury using Method 7470A; antimony, selenium, and thallium using Method 6020; perchlorate using Method 314; and VOCs using Method 8260B. Quality control and quality assurance (QC/QA) samples included 10% replicates and one trip blank for each cooler containing samples for VOC analysis. Samples were packed in ice for shipment to the analytical laboratory as described in the Work Plan (Shaw, 2004).

Samples were packaged with a completed request for analysis and chain of custody records in each sample cooler and shipped to the Kemron Environmental Services laboratory in Marietta, Ohio. Proper personal protective equipment, including hard hat, safety glasses, steel-toed boots, and rubber nitrile gloves were worn during well purging and sampling activities.

2.2 *Summary of Analytical Results*

The September 2004 sampling data indicated a total of 13 dioxin and furan congeners in the groundwater samples collected from LHSMW62 and LHSMW64 with concentrations ranging from 0.153 JK pico grams per liter (pg/L) to 35.034 pg/L (Shaw, 2005). (The JK data qualifier indicates that the value is an estimate of the maximum concentration in the sample). Thallium was also detected at concentrations ranging between 0.142 µg/L and 0.465 µg/L, below the MCL of 2.0 µg/L. Perchlorate was not detected at LHAAP-48. At the intermediate monitoring well 48WW01, dioxins/furans were detected at estimated concentrations ranging between 2.178 J pg/L and 36.101 pg/L (Shaw, 2005).

Analysis of the unfiltered samples collected in May 2005 indicated no detections of dioxin or furan congeners in samples from 48WW01 and LHSMW62. Two congeners were detected in unfiltered samples from LHSMW64, ranging from 2.277 to 3.04 pg/L (**Table 2-1**). Both congener concentrations are below the MCL for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) of 30 pg/L. Samples were not collected from LHSMW63 and LHSMW66 for dioxin and furan analysis due to inadequate recharge.

VOCs, including TCE, that exceeded MCL concentrations in earlier studies (Jacobs, 2002a) were undetected in all unfiltered samples or detected at concentrations below their respective MCLs (**Table 2-1**).

Of the metals measured above detection limits in unfiltered samples, all concentrations were below their respective MCL values except chromium (**Table 2-1**). Chromium exceeded the MCL of 100 µg/L in two monitoring wells, LHSMW62 (715 µg/L) and LHSMW63 (2,510 µg/L). Perchlorate was not detected in unfiltered water from 48WW01, LHSMW64, or LHSMW66. Antimony, arsenic, and thallium, which exceeded MCLs during the previous

Table 2-1
Groundwater Sampling Results from May 2005, LHAAP-48

LOCATION_CODE				48WW01		LHSMW62		LHSMW63		LHSMW64		LHSMW66	
SAMPLE_DATE				5/12/2005		5/12/2005		5/12/2005		5/12/2005		5/12/2005	
SAMPLE_PURPOSE				REG		REG		REG		REG		REG	
CONSTRUCTION MATERIAL				Polyvinyl Chloride		316 Stainless Steel		316 Stainless Steel		316 Stainless Steel		316 Stainless Steel	
SAMPLING_ZONE				INTERMEDIATE		SHALLOW		SHALLOW		SHALLOW		SHALLOW	
Parameter	Units	Filtered	MCL	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Water Quality - Unfiltered													
Turbidity	NTU	NA		3.9		4.4		NA		8.6		NA	
DIOXINS/FURANS - Unfiltered													
1,2,3,4,6,7,8-Heptachlorodibenzofuran	pg/L	N	3.00E+01	55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,4,6,7,8-HpCDD	pg/L	N		55.555	U	25.51	U	NA		1.013	B	NA	
1,2,3,4,7,8,9-Heptachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,4,7,8-Hexachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,6,7,8-Hexachloridibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,6,7,8-Hexachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,7,8,9-Hexachloridibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,7,8,9-Hexachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,7,8-Pentachloridibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
1,2,3,7,8-Pentachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
2,3,4,6,7,8-Hexachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
2,3,4,7,8-Pentachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
2,3,7,8-TCDD	pg/L	N		22.22	U	10.20	UJ	NA		10.42	U	NA	
2,3,7,8-TCDF	pg/L	N		22.222	U	10.204	UJ	NA		10.416	U	NA	
Heptachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
Heptachlorodibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		3.04		NA	
Hexachloridibenzo-p-dioxin	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
Hexachlorodibenzofuran	pg/L	N		55.555	U	25.51	U	NA		26.041	U	NA	
Octachlorodibenzofuran	pg/L	N		111.11	U	51.02	U	NA		52.083	U	NA	
Octachlorodibenzo-p-dioxin	pg/L	N	111.11	U	5.491	B	NA		234.41	J	NA		
Pentachlorodibenzofuran	pg/L	N	55.555	U	25.51	U	NA		26.041	U	NA		
Pentachlorodibenzo-p-dioxin	pg/L	N	55.555	U	25.51	U	NA		26.041	U	NA		
Tetrachlorodibenzofuran, Total	pg/L	N	22.222	U	10.204	U	NA		10.416	U	NA		
Tetrachlorodibenzo-p-dioxin	pg/L	N	22.222	U	10.204	U	NA		2.277		NA		
METALS - Unfiltered													
Aluminum	ug/L	N	6	500.00	JH	230.00	B	2,100.00		69.60	B	2,100.00	JH
Antimony	ug/L	N		1.00	U	1.00	U	1.02		1.00	U	1.00	U
Arsenic	ug/L	N		4.00	U	4.00	U	20.00	U	2.28	J	4.00	U
Barium	ug/L	N		171.00		29.10		68.80		79.00		1,140.00	
Beryllium	ug/L	N	4	10.00	U	10.00	U	10.00	U	10.00	U	10.00	U
Cadmium	ug/L	N		10.00	U	10.00	U	10.00	U	10.00	U	10.00	U
Calcium	ug/L	N		10,600.00		70,000.00		6,300.00		3,020.00		44,400.00	
Chromium	ug/L	N	100	20.00	U	715.00		2,510.00		20.00	U	66.80	
Cobalt	ug/L	N		9.72	J	93.80		3.43	J	20.00	U	2.54	J
Copper	ug/L	N	1300	20.00	U	10.60	J	45.70		20.00	U	5.50	J
Iron	ug/L	N		3,800.00		14,400.00		5,440.00		1,850.00		2,480.00	
Lead	ug/L	N	15	5.00	U	4.22	J	5.00	U	5.00	U	3.47	J
Magnesium	ug/L	N		7,330.00	JH	48,200.00	JH	3,960.00		3,010.00		31,600.00	JH
Manganese	ug/L	N		652.00		1,320.00		33.30		105.00		29.20	
Mercury	ug/L	N		0.20	U	0.20	U	0.20	U	0.20	U	0.20	U
Nickel	ug/L	N		5.41	J	2,660.00		203.00		21.40	J	25.80	J
Potassium	ug/L	N		9,240.00		1,330.00	B	1,130.00		256.00	J	6,030.00	
Selenium	ug/L	N	50	3.15		16.20		0.99	J	0.76	J	1.00	U
Silver	ug/L	N		10.00	U	10.00	U	10.00	U	10.00	U	10.00	U
Sodium	ug/L	N		129,000.00	JH	440,000.00	JH	112,000.00		53,000.00		176,000.00	JH
Thallium	ug/L	N	2	0.20	U	0.20	U	0.20	U	0.20	U	0.11	J
Vanadium	ug/L	N		10.00	U	10.00	U	8.99	J	10.00	U	10.00	U
Zinc	ug/L	N		5.18	J	62.50		20.00	U	20.00	U	10.40	J

Table 2-1
Groundwater Sampling Results from May 2005, LHAAP-48

LOCATION_CODE				48WW01	LHSMW62	LHSMW63	LHSMW64	LHSMW66	
SAMPLE_DATE				5/12/2005	5/12/2005	5/12/2005	5/12/2005	5/12/2005	
SAMPLE_PURPOSE				REG	REG	REG	REG	REG	
CONSTRUCTION MATERIAL				Polyvinyl Chloride	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	
SAMPLING_ZONE				INTERMEDIATE	SHALLOW	SHALLOW	SHALLOW	SHALLOW	
Parameter	Units	Filtered	MCL	Result	Qual	Result	Qual	Result	Qual
PERCHLORATE - Unfiltered									
Perchlorate	ug/L	N		1.00	U			1.00	U
VOLATILES - Unfiltered									
1,1,1,2-Tetrachloroethane	ug/L	N	33	1.00	U	1.00	U	1.00	U
1,1,1-Trichloroethane	ug/L	N	200	1.00	U	1.00	U	1.00	U
1,1,2,2-Tetrachloroethane	ug/L	N	4.3	1.00	U	1.00	U	1.00	U
1,1,2-Trichloroethane	ug/L	N	5	1.00	U	1.00	U	1.00	U
1,1-Dichloroethane	ug/L	N	3650	1.00	U	1.00	U	1.00	U
1,1-Dichloroethene	ug/L	N	7	1.00	U	1.00	U	1.00	U
1,1-Dichloropropene	ug/L	N	0.85	1.00	U	1.00	U	1.00	U
1,2,3-Trichlorobenzene	ug/L	N	110	1.00	U	1.00	U	1.00	U
1,2,3-Trichloropropane	ug/L	N	0.012	1.00	U	1.00	U	1.00	U
1,2,4-Trichlorobenzene	ug/L	N	70	1.00	U	1.00	U	1.00	U
1,2,4-Trimethylbenzene	ug/L	N	1825	1.00	U	1.00	U	1.00	U
1,2-Dibromo-3-chloropropane	ug/L	N	0.2	5.00	U	5.00	U	5.00	U
1,2-Dibromoethane	ug/L	N	5	1.00	U	1.00	U	1.00	U
1,2-Dichlorobenzene	ug/L	N	600	1.00	U	1.00	U	1.00	U
1,2-Dichloroethane	ug/L	N	5	1.00	U	1.00	U	1.00	U
1,2-Dichloropropane	ug/L	N	5	1.00	U	1.00	U	1.00	U
1,2-Dimethylbenzene (o-Xylene)	ug/L	N	10000	1.00	U	1.00	U	1.00	U
1,3,5-Trimethylbenzene	ug/L	N	1825	1.00	U	1.00	U	1.00	U
1,3-Dichlorobenzene	ug/L	N	1095	1.00	U	1.00	U	1.00	U
1,3-Dichloropropane	ug/L	N	8.5	1.00	U	1.00	U	1.00	U
1,4-Dichlorobenzene	ug/L	N	75	1.00	U	1.00	U	1.00	U
2,2-Dichloropropane	ug/L	N	13	1.00	UJ	1.00	UJ	1.00	UJ
2-Butanone	ug/L	N		10.00	U	10.00	U	10.00	UJ
2-Chloroethyl vinyl ether	ug/L	N		10.00	U	10.00	U	10.00	U
2-Chlorotoluene	ug/L	N	730	1.00	U	1.00	U	1.00	U
2-Hexanone	ug/L	N	2200	10.00	UJ	10.00	UJ	10.00	UJ
4-Chlorotoluene	ug/L	N	730	1.00	U	1.00	U	1.00	U
Acetone	ug/L	N	33000	10.00	U	10.00	U	10.00	U
Benzene	ug/L	N	5	1.00	U	1.00	U	1.00	U
Bromobenzene	ug/L	N	730	1.00	U	1.00	U	1.00	U
Bromochloromethane	ug/L	N		1.00	U	1.00	U	1.00	U
Bromodichloromethane	ug/L	N	1.4	1.00	U	1.00	U	1.00	U
Bromoform	ug/L	N	11	1.00	U	1.00	U	1.00	U
Bromomethane	ug/L	N	51.1	1.00	U	1.00	U	1.00	U
Carbon disulfide	ug/L	N	3650	1.00	U	1.00	U	1.00	UJ
Carbon tetrachloride	ug/L	N	5	1.00	U	1.00	U	1.00	U
Chlorobenzene	ug/L	N	100	1.00	U	1.00	U	1.00	U
Chloroethane	ug/L	N	14600	1.00	U	1.00	U	1.00	U
Chloroform	ug/L	N	365	1.00	U	1.00	U	1.00	U
Chloromethane	ug/L	N	66	1.00	U	1.00	U	1.00	U
cis-1,2-Dichloroethene	ug/L	N	70	1.00	U	1.00	U	0.61	JH
cis-1,3-Dichloropropene	ug/L	N	1.6	1.00	U	1.00	U	1.00	U
Dibromochloromethane	ug/L	N	10	1.00	U	1.00	U	1.00	U
Dibromomethane	ug/L	N		1.00	U	1.00	U	1.00	U
Dichlorodifluoromethane	ug/L	N	7300	1.00	U	1.00	U	1.00	U
Ethylbenzene	ug/L	N	700	1.00	U	1.00	U	1.00	U
Hexachlorobutadiene	ug/L	N	7.3	1.00	U	1.00	U	1.00	U
Isopropylbenzene	ug/L	N		1.00	U	1.00	U	1.00	U
m,p-Xylenes	ug/L	N	10000	1.00	U	1.00	U	1.00	U
Methyl isobutyl ketone	ug/L	N	2920	10.00	U	10.00	U	10.00	U

Table 2-1
Groundwater Sampling Results from May 2005, LHAAP-48

LOCATION_CODE				48WW01	LHSMW62	LHSMW63	LHSMW64	LHSMW66
SAMPLE_DATE				5/12/2005	5/12/2005	5/12/2005	5/12/2005	5/12/2005
SAMPLE_PURPOSE				REG	REG	REG	REG	REG
CONSTRUCTION MATERIAL				Polyvinyl Chloride	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel
SAMPLING_ZONE				INTERMEDIATE	SHALLOW	SHALLOW	SHALLOW	SHALLOW
Parameter	Units	Filtered	MCL	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual
Methylene chloride	ug/L	N	5	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
Naphthalene	ug/L	N	730	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
n-BUTYLBENZENE	ug/L	N	1460	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
n-PROPYLBENZENE	ug/L	N	1460	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
p-ISOPROPYLTOLUENE	ug/L	N		1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
sec-BUTYLBENZENE	ug/L	N	1460	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Styrene	ug/L	N	100	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
tert-BUTYLBENZENE	ug/L	N		1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Tetrachloroethene	ug/L	N		1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Toluene	ug/L	N	1000	1.00 U	1.00 U	0.36 J	1.00 U	0.40 J
trans-1,2-Dichloroethene	ug/L	N	100	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
trans-1,3-Dichloropropene	ug/L	N	8.5	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Trichloroethene	ug/L	N	5	1.00 U	1.00 U	1.00 U	0.45 JH	1.00 U
Trichlorofluoromethane	ug/L	N	10950	1.00 UJ	0.28 J	1.00 UJ	1.00 U	1.00 UJ
Vinyl acetate	ug/L	N	36500	10.00 U	10.00 U	10.00 U	10.00 UJ	10.00 U
Vinyl chloride	ug/L	N	2	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
DIOXINS/FURANS - Filtered								
1,2,3,4,6,7,8-Heptachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,4,6,7,8-HpCDD	pg/L	Y		0.82 B	25.77 U	NA	14.73 J	NA
1,2,3,4,7,8,9-Heptachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,4,7,8-Hexachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,6,7,8-Hexachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,7,8,9-Hexachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
1,2,3,7,8-Pentachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
2,3,4,6,7,8-Hexachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
2,3,4,7,8-Pentachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
2,3,7,8-TCDD	pg/L	Y	3.00E+01	11.11 U	10.31 U	NA	10.53 U	NA
2,3,7,8-TCDF	pg/L	Y		11.11 U	10.31 U	NA	10.53 U	NA
Heptachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
Heptachlorodibenzo-p-dioxin	pg/L	Y		0.82	25.77 U	NA	14.73	NA
Hexachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	3.90	NA
Hexachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
Octachlorodibenzofuran	pg/L	Y		55.56 U	51.55 U	NA	52.63 U	NA
Octachlorodibenzo-p-dioxin	pg/L	Y		4.63 B	4.43 B	NA	142.45 J	NA
Pentachlorodibenzofuran	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
Pentachlorodibenzo-p-dioxin	pg/L	Y		27.78 U	25.77 U	NA	26.32 U	NA
Tetrachlorodibenzofuran, Total	pg/L	Y		11.11 U	10.31 U	NA	10.53 U	NA
Tetrachlorodibenzo-p-dioxin	pg/L	Y		11.11 U	10.31 U	NA	10.53 U	NA
METALS - Filtered								
Aluminum	ug/L	Y		66.60 B	93.90 B	1,030	72.00 B	95.10 B
Antimony	ug/L	Y	6	1.00 U	1.00 U	0.84 J	1.00 U	0.52 J
Arsenic	ug/L	Y	10	4.00 U	4.00 U	4.00 U	2.36 J	4.00 U
Barium	ug/L	Y	2000	188.00	84.40	95.10	160.00 J	1,200.00
Beryllium	ug/L	Y	4	10.00 U	10.00 U	10.00 U	10.00 U	10.00 U
Cadmium	ug/L	Y		10.00 U	10.00 U	10.00 U	10.00 U	10.00 U
Calcium	ug/L	Y		11,400	67,000	7,380	4,850	49,100
Chromium	ug/L	Y	100	20.00 U	379.00	60.70	20.00 U	12.00 J
Cobalt	ug/L	Y		8.42 J	113.00	20.00 U	20.00 U	20.00 U
Copper	ug/L	Y	1300	20.00 U	12.70 J	11.80 J	20.00 U	20.00 U

Table 2-1
Groundwater Sampling Results from May 2005, LHAAP-48

LOCATION_CODE				48WW01	LHSMW62	LHSMW63	LHSMW64	LHSMW66
SAMPLE_DATE				5/12/2005	5/12/2005	5/12/2005	5/12/2005	5/12/2005
SAMPLE_PURPOSE				REG	REG	REG	REG	REG
CONSTRUCTION MATERIAL				Polyvinyl Chloride	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel
SAMPLING_ZONE				INTERMEDIATE	SHALLOW	SHALLOW	SHALLOW	SHALLOW
Parameter	Units	Filtered	MCL	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual
Iron	ug/L	Y		83.60 B	17,800	832.00	1,750	57.90 B
Lead	ug/L	Y	15	5.00 U	4.02 J	5.00	5.00	3.07 J
Magnesium	ug/L	Y		7,170	45,800	3,870.00	3,110	34,300 JH
Manganese	ug/L	Y		593.00	1,420.00	17.00	104	10.00 U
Mercury	ug/L	Y		0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Nickel	ug/L	Y		12.60 J	3,580	217.00	22.00 J	14.20 J
Potassium	ug/L	Y		8,430	1,360.00 B	1,000	498	6,070
Selenium	ug/L	Y	50	2.63	13.70	0.77 J	1.03	0.62 J
Silver	ug/L	Y		10.00 U	10.00 U	10.00 U	10.00 U	10.00 U
Sodium	ug/L	Y		131,000	424,000	122,000	62,900	219,000 JH
Thallium	ug/L	Y	2	0.20 U	0.20 U	0.20 U	0.20 U	0.10 J
Vanadium	ug/L	Y		10.00 U	10.00 U	10.00 U	10.00 U	10.00 U
Zinc	ug/L	Y		53.80	77.90	41.90	72.30 J	67.70

Notes and Abbreviations

Results are reported to Method Detection Limit

B The analyte was detected in an associated method blank, equipment rinsate blank, or trip blank (5X/10X rule was applied).

J The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed.

U Not detected. The analyte was analyzed for but not detected above the associated reporting limit.

MCL EPA's Maximum Contaminant Level

NA Not analyzed

pg/L picograms per liter

µg/L micrograms per liter

sampling round (Jacobs 2002a), were either undetected or were detected below their respective MCLs (**Table 2-1**).

Filtered samples collected in May 2005 contained concentrations of dioxin or furan congeners ranging from 0.82 picograms per liter (pg/L) (intermediate monitoring well 48WW01) to 234.41 pg/L, which is a J-qualified concentration of octachlorodibenzo-p-dioxin measured in shallow monitoring well LHSMW64. Because the toxicity equivalency factor (TEF) value of octachlorodibenzo-p-dioxin is 0.0001 (Van den Berg, 1998), the octachlorodibenzo-p-dioxin contribution to the 2,3,7,8-TCDD TEQ concentration would be 0.0234, which is an insignificant contributor to the derived TEQ concentration and well below the MCL for 2,3,7,8-TCDD (30 pg/L). Therefore, the uncertainty associated with the range of dioxin and furan concentrations does not influence the interpretation of the groundwater data for dioxins/furans.

Of the metals detected in filtered samples, only chromium in water from monitoring well LHSMW62 exceeded the MCL of 100 µg/L (379 µg/L), approximately one-half of the concentration in the unfiltered sample (715 µg/L). The chromium concentration in filtered water from LHSMW63 was 60.7 (below the MCL) compared to the value in the unfiltered sample of 2,510 µg/L as shown in **Table 2-1**.

The source of chromium in groundwater from LHAAP-48 wells has been discussed previously. The Jacobs (2002) report characterized 50 soil samples and 10 groundwater samples for contamination associated with sumps and other potential sources and concluded in Section 10.5 that chromium was not found in soil near the sumps at LHAAP-48, and that the sumps "... may have been a limited source of a variety of contamination. However, there is no widespread soil contamination or significantly organic-contaminated groundwater, which indicates that the sources are probably small and isolated and have not contributed to significant migration of contaminants."

Regarding metals, the report found, "The low levels of metals contaminants in the Site 48 soils are mostly barium, cadmium, and lead.", and "The soil metals may migrate slowly via infiltrating precipitation. The low metals levels of these metals in groundwater suggest no significant leaching. However, the presence of elevated chromium levels in groundwater suggests an unidentified or no longer remaining source in the soils at Site 48."

The Plexus (2005) report (Section 6.10) describes the LHAAP-48 (Area Y) buildings, which were used initially for production of illuminating devices. In later years the site was dedicated to preparation of black powder, and buildings and equipment were periodically washed as a safety measure to reduce accumulation of hazardous dusts. Because these washings were collected in some of the 12 Area Y waste sumps, it is reasonable to expect that LHAAP-48 contaminants identified in groundwater would be found in soil near the sumps also.

The Plexus (2005) report identifies Building 34-Y as the mixing area for pyrotechnic materials for hand signals, colored smokes, and illuminant materials, although none of the materials handled in this building contained chromium compounds. The report references Buildings 16-Y, 38-Y, and 48-Y as locations where illuminants, colored smoke compositions were handled, and delay composition, which contains barium chromate.

In summary, the results of Jacobs (2002) and Plexus (2005) evaluations indicate that chromium may have been handled in some LHAAP-48 buildings, and would be expected to be included in building washings diverted to sumps, but chromium was not detected in soil.

Data from analysis of groundwater from wells at LHAAP 48 and 53(35C) are shown in **Table 2-1** and **Table 3-1**. All of the wells have 316 stainless steel screens except for Well 48WW01, Well 107, and the piezometer wells, which have polyvinyl chloride (PVC) screens. Well construction diagrams are included in **Appendix E**. Groundwater samples with chromium concentrations above the MCL are from stainless steel-screened wells only. All groundwater from PVC-screened wells contains undetected or low estimated (J-qualified) chromium and nickel concentrations, including the highly turbid samples from wells PZ002 and PZ004.

The observations that chromium was not detected in soil associated with the expected source sumps, and elevated chromium concentrations were detected only in wells with stainless steel screens, suggest that the chromium in groundwater is associated with corroded screens and represents the unknown source suggested in the Jacobs (2002) report.

To test this hypothesis, a new well with PVC casing material (48WW02) was installed near LHSMW62 and sampled in September 2006. Chromium concentrations in groundwater samples from this well (**Table 2-2**) indicate undetected or low estimated concentrations well below the MCL for chromium and well below the concentrations observed in well LHSMW62. These results support the hypothesis that chromium concentrations in groundwater from LHSMW62 originated from stainless steel casing used in that well (**Table 2-1**), and not from chromium in soil.

To summarize, the chemicals that accounted for the human health risk and hazard from groundwater were either nondetect or below MCLs when analyzed in groundwater collected by low-flow methods (see **Section 2.2**). The detection of chromium at one well, marginally exceeds the MCL concentration, but appears to be associated with sediments, and associated well construction materials. These detections do not provide a strong indication of a release of chromium associated with LHAAP-48 operations.

Table 2-2
Groundwater Sampling Results from Well Installed Near LHSMW62, LHAAP-48

Location Code Sample No Sample Date				48WW02 48WW02-092006 20-Sep-06		
Test Group	Parameter	Filtered	Units	Result	Qual	ValQual
METALS	Chromium	N	µg/L	6.24	J	J
METALS	Chromium	Y	µg/L	20	U	U

Notes and Abbreviations:

N Sample was filtered before analysis
J Estimated result detected above the method detection limit but below the method quantitation limit
Qual Data qualifier provided by analytical laboratory
U Chromium was not detected below the sample quantitation limit shown
ValQual Data validation qualifier assigned during data validation process
Y Sample was not filtered before analysis

3.0 *LHAAP-35C(53) Groundwater Sampling in 2004 and 2005*

In September 2004 groundwater samples were collected from all seven monitoring wells at LHAAP-35C(53) (**Figure 2-1**). Samples from monitoring wells 107, LHSMW68, LHSMW69, and LHSMW70 were analyzed for VOCs and perchlorate. The sample from monitoring well LHSMW67 was analyzed for VOCs, perchlorate, and dioxins/furans, and the sample from monitoring well LHSMW71 was analyzed for VOCs, perchlorate, and metals (filtered and unfiltered). Detections of dioxins/furans and metals were suspected to be related to sample turbidity (Shaw, 2005). Previous sampling events had indicated elevated chromium in well LHSMW71. Therefore, an additional sampling event was conducted in May 2005 in order to analyze for filtered and unfiltered metals. Groundwater samples were collected from all seven monitoring wells and were analyzed for dioxins/furans and metals, filtered and unfiltered, and VOCs in order to confirm the presence and current concentrations of these compounds. Groundwater samples were also collected from three piezometers (PZ001, PZ002, and PZ004) present at the site to determine if chromium and VOCs were pervasive at the site. Results of the May 2005 sampling and analysis are discussed below.

3.1 *Groundwater Sampling and Analytical Methods*

In May 2005, Shaw sampled seven groundwater monitoring wells and three piezometers at LHAAP-35C(53). Prior to sampling, the wells were gauged for water levels and the well bottom depths were verified. Low-flow sampling methods were employed, using downhole bladder pumps and disposable tubing. Prior to sampling, water quality measurements were recorded including turbidity, dissolved oxygen, pH, conductivity, temperature, and oxidation reduction potential using a water quality instrument with a flow-through cell. After stable readings indicated that appropriate water quality objectives have been met according to the site-specific standard operating procedures established for LHAAP groundwater sampling activities (Shaw, 2004), groundwater samples were collected. The recharge rate at monitoring well LHSMW71 did not sustain low-flow sampling and the well was purged dry prior to sampling with a peristaltic pump the following day (within 24 hours). Sampling activities were completed on May 13, 2005. Copies of the groundwater sampling forms are included as **Appendix B**. Piezometer sampling was conducted using a peristaltic pump because low-flow sampling could not be sustained. Samples were limited due to slow recharge rates. Water quality parameters could not be measured and the piezometer samples were not analyzed for dioxins/furans.

Filtered and unfiltered groundwater samples were analyzed for dioxins/furans and metals using USEPA SW-846 Methods 8290 and 6010B, respectively (USEPA, 1983). Samples were also analyzed for mercury using Method 7470A, and antimony, selenium, and thallium using Method 6020. Groundwater samples collected from the piezometers were analyzed for TAL Metals

using Methods 6010B, 6020, 7470A, and VOCs using Method 8260B. Quality control and quality assurance (QC/QA) samples included 10% replicates and one trip blank for each cooler containing samples for VOC analysis. Samples were packed in ice for shipment to the analytical laboratory as described in the Work Plan (Shaw, 2004).

Samples were packaged with a completed request for analysis and chain of custody records in each sample cooler and shipped to the Kemron Environmental Services laboratory in Marietta, Ohio. Proper personal protective equipment, including hard hat, safety glasses, steel-toed boots, and rubber nitrile gloves were worn during development and sampling activities.

3.2 *Summary of Analytical Results*

In September 2004, groundwater samples were collected from all seven monitoring wells at LHAAP-35C(53) and analyzed for dioxins/furans, perchlorate, VOCs, and metals. A total of six dioxins/furans were detected in the groundwater samples, with concentrations ranging from 0.934 pg/L to 67.19 pg/L at shallow monitoring well LHSMW67 located on the northern portion of LHAAP-35C(53). VOCs and perchlorate were not detected in any of the groundwater samples collected at LHAAP-35C(53) (Shaw, 2005). Samples from well LHSMW-71 showed detections of thallium and chromium. Thallium was detected at concentrations of 0.276 µg/L and 0.224 µg/L in unfiltered and filtered samples, respectively, below the MCL of 2.0 µg/L. Chromium was detected at a concentration of 83,300 µg/L in the unfiltered sample from LHSMW71. However, the concentration in the filtered sample was much lower at 16 J µg/L, indicating that chromium was attached to particulates (Shaw, 2005).

In May 2005 seven monitoring wells and three piezometers were sampled for dioxins/furans and metals (filtered and unfiltered), and VOCs. Sampling results from the unfiltered samples indicated detections of dioxin/furans ranging from 1.013B pg/L (shallow monitoring well LHSMW67) to 93.325 pg/L (shallow monitoring well LHSMW68); however, none were above MCLs (**Table 3-1**). The results also showed detections of several metals, including antimony (6.58 µg/L, well LHSMW67), and chromium (171 µg/L, well LHSMW71), above their MCLs of 10 µg/L and 100 µg/L, respectively. Thallium, which was the primary driver for non-cancer hazard during the industrial risk assessment by Jacobs (2003) was nondetect or below the MCL (**Table 3-1**). There were no VOCs observed above the detection limits in the seven monitoring wells. The filtered groundwater sampling results from May 2005 sampling of the seven monitoring wells indicate several detections of dioxin/furans in each monitoring well, but none above the MCL (Table 3-1). Antimony slightly exceeded the MCL of 6 µg/L in monitoring well LHSMW67 (6.58 µg/L). Note that antimony was not detected in the unfiltered sample; thus, the results of the filtered sample analysis are suspect. Cis-1,2-dichloroethylene (1.19 µg/L) was detected below the MCL of 70 µg/L and TCE (5.01 µg/L) was detected near the MCL concentration (5.0 µg/L). Antimony, arsenic, and lead were above MCLs in the unfiltered

Table 3-1
Groundwater Sampling Results from May 2005, LHAAP-35C(53)

LOCATION_CODE FK_SAMPLE_DATE SAMPLE_NO SAMPLE_DATE SAMPLE_PURPOSE CONSTRUCTION MATERIAL SAMPLING_ZONE Parameter	Units	MCL	107 20050512 35CWW107-MAY05 5/12/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW67 20050513 LHSMW67-MAY05 5/13/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW68 20050511 LHSMW68-MAY05 5/11/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW69 20050512 LHSMW69-MAY05 5/12/2005 REG 316 Stainless Steel INTERMEDIATE Result Qual	LHSMW70 20050512 LHSMW70-MAY05 5/12/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW71 20050514 LHSMW71-MAY05 5/14/2005 REG 316 Stainless Steel SHALLOW Result Qual	PZ001 20050513 PZ001-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual	PZ002 20050513 PZ002-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual	PZ004 20050513 PZ004-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual
WATER QUALITY - UNFILTERED											
TURBIDITY	NTU		10.2	31.2	5.1	1.4	-2.5	NA	10.1	82.2	431
DIOXINS/FURANS - UNFILTERED											
1,2,3,4,6,7,8-Heptachlorodibenzofuran	pg/L		2.49 U	0.354 U	1.386 B	0.322 U	0.544 UJ	0.265 U	NA	NA	NA
1,2,3,4,6,7,8-HpCDD	pg/L		3.512 U	1.013 B	8.736 B	0.257 U	5.921 BJ	2.084 B	NA	NA	NA
1,2,3,4,7,8,9-Heptachlorodibenzofuran	pg/L		4.572 U	0.457 U	0.536 U	0.452 U	0.764 UJ	0.342 U	NA	NA	NA
1,2,3,4,7,8-Hexachlorodibenzofuran	pg/L		1.733 U	0.274 U	0.242 U	0.186 U	0.253 U	0.279 U	NA	NA	NA
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	pg/L		3.1 U	0.455 U	0.37 U	0.331 U	0.395 U	0.441 U	NA	NA	NA
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	pg/L		3.014 U	0.41 U	0.357 U	0.319 U	0.38 U	0.397 U	NA	NA	NA
1,2,3,6,7,8-Hexachlorodibenzofuran	pg/L		1.617 U	0.271 U	0.253 U	0.194 U	0.265 U	0.276 U	NA	NA	NA
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	pg/L		3.213 U	0.423 U	0.352 U	0.315 U	0.376 U	0.41 U	NA	NA	NA
1,2,3,7,8,9-Hexachlorodibenzofuran	pg/L		2.676 U	0.324 U	0.312 U	0.239 U	0.326 U	0.33 U	NA	NA	NA
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	pg/L		2.869 U	0.517 U	0.311 U	0.47 U	0.377 U	0.441 U	NA	NA	NA
1,2,3,7,8-Pentachlorodibenzofuran	pg/L		1.951 U	0.355 U	0.261 U	0.265 U	0.23 U	0.317 U	NA	NA	NA
2,3,4,6,7,8-Hexachlorodibenzofuran	pg/L		1.895 U	0.289 U	0.271 U	0.207 U	0.283 U	0.295 U	NA	NA	NA
2,3,4,7,8-Pentachlorodibenzofuran	pg/L		1.956 U	0.332 U	0.251 U	0.255 U	0.222 U	0.296 U	NA	NA	NA
2,3,7,8-TCDD	pg/L	3.00E+01	2.937 U	0.965 UJ	0.598 U	0.537 U	0.267 U	0.681 U	NA	NA	NA
2,3,7,8-TCDF	pg/L		2.437 U	1.215 UJ	0.706 U	0.859 U	0.492 U	0.67 U	NA	NA	NA
Heptachlorodibenzofuran	pg/L		2.49 U	0.354 U	5.886 U	0.322 U	0.544 U	0.265 U	NA	NA	NA
Heptachlorodibenzo-p-dioxin	pg/L		3.512 U	2.191 U	22.633 U	0.257 U	9.768 U	4.91 U	NA	NA	NA
Hexachloridibenzo-p-dioxin	pg/L		3.014 U	0.41 U	0.357 U	0.319 U	0.38 U	0.397 U	NA	NA	NA
Hexachlorodibenzofuran	pg/L		1.617 U	0.274 U	0.242 U	0.186 U	0.253 U	0.279 U	NA	NA	NA
Octachlorodibenzofuran	pg/L		9.814 U	0.702 U	8.803 B	0.531 U	1.153 U	0.448 U	NA	NA	NA
Octachlorodibenzo-p-dioxin	pg/L		20.638 J	17.253 B	93.325 B	9.246 B	79.658 BJ	27.25 B	NA	NA	NA
Pentachlorodibenzofuran	pg/L		1.956 U	0.332 U	0.251 U	0.255 U	0.222 U	0.296 U	NA	NA	NA
Pentachlorodibenzo-p-dioxin	pg/L		2.869 U	0.517 U	0.311 U	0.47 U	0.377 U	0.441 U	NA	NA	NA
Tetrachlorodibenzofuran, Total	pg/L		2.437 U	1.215 U	0.706 U	0.859 U	0.492 U	0.67 U	NA	NA	NA
Tetrachlorodibenzo-p-dioxin	pg/L		2.937 U	0.965 U	0.598 U	0.537 U	0.267 U	0.681 U	NA	NA	NA
METALS - UNFILTERED											
Aluminum	ug/L		1270 JH	8210 JH	1120 U	69.1 J	61.3 B	98.6 B	288 JH	13300 JH	13000 JH
Antimony	ug/L	6	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5.77	6.17
Arsenic	ug/L	10	2 U	2.83 J	2 U	2 U	2 U	2 U	2 U	31.3	34.8
Barium	ug/L	2000	91.6	168	15	99.6	163	33.6	71.4	138	264
Beryllium	ug/L	4	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.414 J	1.6 J
Cadmium	ug/L		2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Calcium	ug/L		8690	4470	234	3810	14100	6010	36300	11000	10900
Chromium	ug/L	100	2.5 U	40	13.6 J	2.5 U	2.5 U	171	2.5 U	23.5	15.1 J
Cobalt	ug/L		17.4 J	4.94 J	2.5 U	2.5 U	3.85 J	12.8 J	2.5 U	13.9 J	29.7
Copper	ug/L	1300	5 U	6.06 J	5 U	5 U	5 U	5 U	5 U	11.5 J	9.46 J
Iron	ug/L		2860	6940	993	464	9170	1100	313	15600	10200
Lead	ug/L	15	2.5 U	3.66 J	2.5 U	2.5 U	2.5 U	2.5 U	2.7 J	18.9	19
Magnesium	ug/L		7660 JH	3060 JH	758	3030	6630	6190	20100 JH	5950 JH	6440 JH
Manganese	ug/L		258	31	8.19 B	82.5	480	121	68.6	101	180
Mercury	ug/L		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.971	1.32	0.1 U	0.1 U
Nickel	ug/L		8.08 J	218	5 U	20.9 J	30 J	516	37.8 J	48.3	30.9 J
Potassium	ug/L		2750	860 J	495 J	278 J	1790 B	715 B	2030	2450	2540
Selenium	ug/L	50	4.05	5.32	0.5 U	3.14	1.5	3.82	12.6	2.89	6.64
Silver	ug/L		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Sodium	ug/L		141000 JH	142000 JH	15200	59600	97100	252000	594000 JH	88500 JH	163000 JH
Thallium	ug/L	2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.188 J	0.225	
Vanadium	ug/L		5 U	11.6	5 U	5 U	5 U	5 U	5 U	26.4	23.4
Zinc	ug/L		17.7 J	53.1	5 U	36.7	50.2	5 U	5 U	55.5	56.3

Table 3-1
Groundwater Sampling Results from May 2005, LHAAP-35C(53)

LOCATION_CODE			107	LHSMW67	LHSMW68	LHSMW69	LHSMW70	LHSMW71	PZ001	PZ002	PZ004
FK_SAMPLE_DATE			20050512	20050513	20050511	20050512	20050512	20050514	20050513	20050513	20050513
SAMPLE_NO			35CWW107-MAY05	LHSMW67-MAY05	LHSMW68-MAY05	LHSMW69-MAY05	LHSMW70-MAY05	LHSMW71-MAY05	PZ001-MAY05	PZ002-MAY05	PZ004-MAY05
SAMPLE_DATE			5/12/2005	5/13/2005	5/11/2005	5/12/2005	5/12/2005	5/14/2005	5/13/2005	5/13/2005	5/13/2005
SAMPLE_PURPOSE			REG	REG	REG	REG	REG	REG	REG	REG	REG
CONSTRUCTION MATERIAL			316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	Polyvinyl Chloride	Polyvinyl Chloride	Polyvinyl Chloride
SAMPLING_ZONE			SHALLOW	SHALLOW	SHALLOW	INTERMEDIATE	SHALLOW	SHALLOW	N/A	N/A	N/A
Parameter	Units	MCL	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual
VOLATILES - UNFILTERED											
1,1,1,2-Tetrachloroethane	ug/L	33	0.25 U	0.25 U	0.25 UJ	0.25 U	0.25 U	0.25 UJ	0.25 U	0.25 U	0.25 U
1,1,1-Trichloroethane	ug/L	200	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,1,2,2-Tetrachloroethane	ug/L	4.3	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
1,1,2-Trichloroethane	ug/L	5	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,1-Dichloroethane	ug/L	3650	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
1,1-Dichloropropene	ug/L	7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropene	ug/L	0.85	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,2,3-Trichlorobenzene	ug/L	110	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
1,2,3-Trichloropropane	ug/L	0.012	0.75 U	0.75 U	0.75 U	0.75 U	0.75 U	0.75 U	0.75 U	0.75 U	0.75 U
1,2,4-Trichlorobenzene	ug/L	70	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2,4-Trimethylbenzene	ug/L	1825	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,2-Dibromo-3-chloropropane	ug/L	0.2	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
1,2-Dibromoethane	ug/L	5	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,2-Dichlorobenzene	ug/L	600	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
1,2-Dichloroethane	ug/L	5	0.25 U	2.45	0.25 U	0.655 JH	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,2-Dichloropropane	ug/L	5	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
1,2-Dimethylbenzene (o-Xylene)	ug/L	10000	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,3,5-Trimethylbenzene	ug/L	1825	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,3-Dichlorobenzene	ug/L	1095	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,3-Dichloropropane	ug/L	8.5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,4-Dichlorobenzene	ug/L	75	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
2,2-Dichloropropane	ug/L	13	0.25 UJ	0.25 UJ	0.25 U	0.25 U	0.25 UJ	0.25 UJ	0.25 UJ	0.25 UJ	0.25 UJ
2-Butanone	ug/L		2.5 U	2.5 U	2.5 UJ	2.5 UJ	2.5 UJ	2.5 U	2.5 U	2.5 U	2.5 U
2-Chloroethyl vinyl ether	ug/L		2 U	2 U	2 UJL	2 U	2 U	2 U	2 U	2 U	2 U
2-Chlorotoluene	ug/L	730	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
2-Hexanone	ug/L	2200	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ	2.5 UJ
4-Chlorotoluene	ug/L	730	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Acetone	ug/L	33000	2.5 U	2.5 U	2.5 UJ	2.5 U	2.5 U	2.8 J	2.5 U	2.5 U	2.5 U
Benzene	ug/L	5	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
Bromobenzene	ug/L	730	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
Bromochloromethane	ug/L		0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Bromodichloromethane	ug/L	1.4	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Bromoform	ug/L	11	0.54 U	0.54 U	0.54 U	0.54 U	0.54 U	0.54 U	0.54 U	0.54 U	0.54 U
Bromomethane	ug/L	51.1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon disulfide	ug/L	3650	0.5 U	0.5 U	0.5 UJ	0.5 UJ	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U
Carbon tetrachloride	ug/L	5	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Chlorobenzene	ug/L	100	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
Chloroethane	ug/L	14600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	ug/L	365	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
Chloromethane	ug/L	66	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
cis-1,2-Dichloroethene	ug/L	70	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	1.19
cis-1,3-Dichloropropene	ug/L	1.6	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Dibromochloromethane	ug/L	10	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Dibromomethane	ug/L		0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Dichlorodifluoromethane	ug/L	7300	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Ethylbenzene	ug/L	700	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Hexachlorobutadiene	ug/L	7.3	0.25 U	0.25 U	0.25 UJ	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Isopropylbenzene	ug/L		0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
m,p-Xylenes	ug/L	10000	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl isobutyl ketone	ug/L	2920	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Methylene chloride	ug/L	5	0.25 U	0.25 U	0.863 B	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Naphthalene	ug/L	730	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U
n-BUTYLBENZENE	ug/L	1460	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
n-PROPYLBENZENE	ug/L	1460	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
p-ISOPROPYLTOLUENE	ug/L		0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
sec-BUTYLBENZENE	ug/L	1460	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Styrene	ug/L	100	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U	0.125 U
tert-BUTYLBENZENE	ug/L		0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Tetrachloroethene	ug/L		0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.969 J
Toluene	ug/L	1000	0.25 U	0.25 U	0.25 U	0.25 U	0.322 J	0.25 U	0.25 U	0.25 U	0.25 U
trans-1,2-Dichloroethene	ug/L	100	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
trans-1,3-Dichloropropene	ug/L	8.5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene	ug/L	5	0.25 U	0.25 U	0.25 U	0.8 JH	0.25 U	0.25 U	0.25 U	0.25 U	5.01
Trichlorofluoromethane	ug/L	10950	0.25 UJ	0.25 UJ	0.25 U	0.25 U	0.25 UJ	0.25 UJ	28.8 J	0.25 UJ	0.25 UJ
Vinyl acetate	ug/L	36500	2.5 U	2.5 U	2.5 U	2.5 UJ	2.5 UJ	2.5 U	2.5 U	2.5 U	2.5 U
Vinyl chloride	ug/L	2	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U

Table 3-1
Groundwater Sampling Results from May 2005, LHAAP-35C(53)

LOCATION_CODE			107	LHSMW67	LHSMW68	LHSMW69	LHSMW70	LHSMW71	PZ001	PZ002	PZ004
FK_SAMPLE_DATE			20050512	20050513	20050511	20050512	20050512	20050514	20050513	20050513	20050513
SAMPLE_NO			35CWW107-MAY05	LHSMW67-MAY05	LHSMW68-MAY05	LHSMW69-MAY05	LHSMW70-MAY05	LHSMW71-MAY05	PZ001-MAY05	PZ002-MAY05	PZ004-MAY05
SAMPLE_DATE			5/12/2005	5/13/2005	5/11/2005	5/12/2005	5/12/2005	5/14/2005	5/13/2005	5/13/2005	5/13/2005
SAMPLE_PURPOSE			REG	REG	REG	REG	REG	REG	REG	REG	REG
CONSTRUCTION MATERIAL			316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	316 Stainless Steel	Polyvinyl Chloride	Polyvinyl Chloride	Polyvinyl Chloride
SAMPLING_ZONE			SHALLOW	SHALLOW	SHALLOW	INTERMEDIATE	SHALLOW	SHALLOW	N/A	N/A	N/A
Parameter	Units	MCL	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual	Result Qual
DIOXINS/FURANS - FILTERED											
1,2,3,4,6,7,8-Heptachlorodibenzofuran	pg/L		0.302 U	0.352 U	0.388 U	0.276 U	0.372 U	0.411 U	NA	NA	NA
1,2,3,4,6,7,8-HpCDD	pg/L		2.491 B	0.524 U	0.227 U	0.594 B	2.776 B	1.059 B	NA	NA	NA
1,2,3,4,7,8,9-Heptachlorodibenzofuran	pg/L		0.424 U	0.455 U	0.544 U	0.387 U	0.522 U	0.531 U	NA	NA	NA
1,2,3,4,7,8-Hexachlorodibenzofuran	pg/L		0.174 U	0.38 U	0.2 U	0.184 U	0.143 U	0.304 U	NA	NA	NA
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	pg/L		0.421 U	0.553 U	0.399 U	0.378 U	0.278 U	0.369 U	NA	NA	NA
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	pg/L		0.405 U	0.497 U	0.385 U	0.364 U	0.268 U	0.332 U	NA	NA	NA
1,2,3,6,7,8-Hexachlorodibenzofuran	pg/L		0.181 U	0.376 U	0.209 U	0.192 U	0.149 U	0.3 U	NA	NA	NA
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	pg/L		0.4 U	0.514 U	0.38 U	0.359 U	0.265 U	0.343 U	NA	NA	NA
1,2,3,7,8,9-Hexachlorodibenzofuran	pg/L		0.223 U	0.449 U	0.257 U	0.236 U	0.184 U	0.359 U	NA	NA	NA
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	pg/L		0.419 U	0.606 U	0.389 U	0.319 U	0.287 U	0.392 U	NA	NA	NA
1,2,3,7,8-Pentachlorodibenzofuran	pg/L		0.22 U	0.308 U	0.262 U	0.19 U	0.178 U	0.315 U	NA	NA	NA
2,3,4,6,7,8-Hexachlorodibenzofuran	pg/L		0.194 U	0.401 U	0.224 U	0.205 U	0.16 U	0.32 U	NA	NA	NA
2,3,4,7,8-Pentachlorodibenzofuran	pg/L		0.212 U	0.288 U	0.252 U	0.183 U	0.171 U	0.294 U	NA	NA	NA
2,3,7,8-TCDD	pg/L	3.00E+01	0.365 U	0.624 U	0.426 U	0.348 U	0.316 U	0.478 U	NA	NA	NA
2,3,7,8-TCDF	pg/L		0.837 U	0.763 U	0.745 U	0.859 U	0.543 U	0.564 U	NA	NA	NA
Heptachlorodibenzofuran	pg/L		0.302 U	0.352 U	0.388 U	0.276 U	0.372 U	0.411 U	NA	NA	NA
Heptachlorodibenzo-p-dioxin	pg/L		4.63	1.948	0.227 U	0.173 U	2.776	0.335 U	NA	NA	NA
Hexachlorodibenzo-p-dioxin	pg/L		0.405 U	0.497 U	0.385 U	0.364 U	0.268 U	0.332 U	NA	NA	NA
Hexachlorodibenzofuran	pg/L		0.174 U	0.38 U	0.2 U	0.184 U	0.143 U	0.304 U	NA	NA	NA
Octachlorodibenzofuran	pg/L		0.701 U	0.807 U	0.564 U	0.437 U	0.519 U	0.677 U	NA	NA	NA
Octachlorodibenzo-p-dioxin	pg/L		21.886 B	13.794 B	7.952 B	12.916 B	34.013 B	16.161 B	NA	NA	NA
Pentachlorodibenzofuran	pg/L		0.212 U	0.288 U	0.252 U	0.183 U	0.171 U	0.294 U	NA	NA	NA
Pentachlorodibenzo-p-dioxin	pg/L		0.419 U	0.606 U	0.389 U	0.319 U	0.287 U	0.392 U	NA	NA	NA
Tetrachlorodibenzofuran, Total	pg/L		0.837 U	0.763 U	0.745 U	0.859 U	0.543 U	0.564 U	NA	NA	NA
Tetrachlorodibenzo-p-dioxin	pg/L		0.365 U	0.624 U	0.426 U	0.348 U	0.316 U	0.478 U	NA	NA	NA

Table 3-1
Groundwater Sampling Results from May 2005, LHAAP-35C(53)

LOCATION_CODE FK_SAMPLE_DATE SAMPLE_NO SAMPLE_DATE SAMPLE_PURPOSE CONSTRUCTION MATERIAL SAMPLING_ZONE Parameter	Units	MCL	107 20050512 35CWW107-MAY05 5/12/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW67 20050513 LHSMW67-MAY05 5/13/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW68 20050511 LHSMW68-MAY05 5/11/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW69 20050512 LHSMW69-MAY05 5/12/2005 REG 316 Stainless Steel INTERMEDIATE Result Qual	LHSMW70 20050512 LHSMW70-MAY05 5/12/2005 REG 316 Stainless Steel SHALLOW Result Qual	LHSMW71 20050514 LHSMW71-MAY05 5/14/2005 REG 316 Stainless Steel SHALLOW Result Qual	PZ001 20050513 PZ001-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual	PZ002 20050513 PZ002-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual	PZ004 20050513 PZ004-MAY05 5/13/2005 REG Polyvinyl Chloride N/A Result Qual
METALS - FILTERED											
Aluminum	ug/L		145 B	11100 JH	979	52.6 J	80.1 B	82.6 B	94.7 B	2110 JH	5460 JH
Antimony	ug/L	6	0.5 U	6.58	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	4.83
Arsenic	ug/L	10	2 U	2.09 J	2 U	2.83 J	2 U	2 U	2 U	2.63 J	29.4
Barium	ug/L	2000	96.2	113	36.6	140 J	12.7 J	91.6	122	125	251
Beryllium	ug/L	4	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.579 J
Cadmium	ug/L		2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Calcium	ug/L		9740	3700	1060	13900	271 B	6670	37000	7140	11400
Chromium	ug/L	100	2.5 U	34.1	2.5 U	8.53 J	2.5 U	3.39 J	2.5 U	2.5 U	5.25 J
Cobalt	ug/L		16.3 J	5.69 J	2.5 U	4.65 J	30.4	10.8 J	2.5 U	5.01 J	21.6
Copper	ug/L	1300	5 U	6.33 J	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Iron	ug/L		1030	9010	705	16400	82.8 B	64.4 B	85.2 B	2490	3980
Lead	ug/L	15	2.5 U	3.82 J	2.5 U	2.5 U	2.5 U	2.5 U	2.63 J	2.7 J	15.7
Magnesium	ug/L		7620	3340 JH	772	6960	521	5980	20300 JH	4330 JH	5530 JH
Manganese	ug/L		243	28.7	4.88 B	535	496	101	51	54.2	148
Mercury	ug/L		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	1.15	1.16	0.1 U	0.1 U
Nickel	ug/L		10.6 J	239	5 U	30.7 J	5 U	488	37.6 J	27.2 J	22 J
Potassium	ug/L		2520	977 J	388 J	2030	332 B	774 B	2370	839 J	1750
Selenium	ug/L	50	4.17	3.59	0.5 U	1.62	1.74	13.3	13.6	1.88	10.6
Silver	ug/L		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Sodium	ug/L		147,000	170,000 JH	21,100	100,000	37,500	242,000	605,000 JH	105,000 JH	171,000 JH
Thallium	ug/L	2	0.1 U	0.103 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.127 J
Vanadium	ug/L		5 U	15.1	5 U	5 U	5 U	5 U	5 U	5 U	9.3 J
Zinc	ug/L		32.1	54.6	5 U	10.9 J	5.33 J	5 U	5 U	44.1	40.2

Notes and Abbreviations

Results are reported to Method Detection Limit

B The analyte was detected in an associated method blank, equipment rinsate blank, or trip blank (5X/10X rule was applied).

J The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed.

U Not detected. The analyte was analyzed for but not detected above the associated reporting limit.

MCL EPA's Maximum Contaminant Level

NA Not analyzed

pg/L picograms per liter

µg/L micrograms per liter

piezometer samples at maximum concentrations of 6.17 µg/L, 34.8 µg/L, and 19 µg/L, respectively. Elevated concentrations of the three metals were observed in piezometers PZ002 and PZ004 that had elevated high turbidity values of 82.2 and 431 NTUs, respectively, during sampling (**Table 3-1**). Arsenic was observed in the filtered sample collected from PZ004 at a concentration of 29.4 µg/L, which is above the MCL of 10 µg/L; and lead was detected at a concentration of 15.7 µg/L, which is slightly above the MCL of 15 µg/L. Elevated concentrations of organic chemicals and lead are considered turbidity related. Nevertheless, the 2005 analysis indicated that chromium was not a site-related contaminant and was attributed to corrosion of the stainless steel screen material used in construction of these wells. The increases in chromium concentration were accompanied by increases in iron and aluminum concentration. **Table 3-1** summarizes the May 2005 groundwater sampling results for LHAAP-35C(53).

To summarize, the chemicals that accounted for the human health risk and hazard to a future maintenance worker (Jacobs, 2003) were shown to be associated with turbidity in the samples. When collected using low flow methods, these chemicals were either not detected or were below MCLs. Detections of other metals were sporadically present but marginally exceeded the MCLs.

4.0 *Summary of the Residential Risk Assessment for Hypothetical Residential Use*

The baseline risk assessments for residential use of LHAAP-48 and LHAAP-35C(53) (**Appendix C** and **D**, respectively), completed by Shaw supplement the information presented in the industrial risk assessment (Jacobs, 2003) and provides risk managers information about whether the sites can be released for unrestricted use (no land use controls [LUCs]). The baseline risk assessments for residential use of LHAAP-48 and LHAAP-35C(53) (**Appendix C** and **D**, respectively) use the same methods employed for the industrial risk assessment (Jacobs, 2003), so the two assessments are consistent. Some adjustments to the methods used for the industrial risk assessment were made, as appropriate, to present a residential assessment that is consistent with other risk assessments being conducted for LHAAP sites, and with current regulatory guidance. The assessment of potential risk to residents was based on Texas Commission on Environmental Quality (TCEQ) Risk Reduction Rules (TCEQ, 1998, 2004) and USEPA guidance.

4.1 *Elements of the Residential Risk Assessment*

The residential risk assessments for LHAAP-48 and LHAAP-35C(53) (**Appendix C** and **D**, respectively) were conducted using data reported in the industrial risk assessment (Jacobs, 2003) supplemented by data from the 2004 and 2005 groundwater sampling by Shaw. The elements of the residential risk assessments include a data evaluation in which chemicals of potential concern (COPC) were identified by comparing soil concentrations (Jacobs, 2003) to LHAAP background concentrations and risk-based screening criteria. Also included in **Appendix C** and **D** are an exposure assessment that describes land use assumptions, plausible human exposure scenarios and receptors, and quantitative estimates of their potential exposure. In addition, a toxicity evaluation is included that briefly describes the adverse health effects associated with each COPC and provides references for further details; a risk characterization that qualitatively describes cancer risk and noncancer hazard to human receptors; an uncertainty analysis that describes the uncertainties associated with the components of the risk assessment and their impact on the conclusions and future decisions regarding the site. A detailed account of the residential BHHRA process is included in **Appendix C** for LHAAP-48 and **Appendix D** for LHAAP-35C(53).

4.2 *Results of the Residential Risk Assessment*

The assessment of risk to a hypothetical resident from exposure to chemicals in soil at LHAAP-48 and LHAAP-35C(53) indicate that potential risks are within the acceptable range established by USEPA (1994) guidance.

All cancer risk estimates that exceed $1\text{E-}06$ for potential residential use of LHAAP-48 are associated with exposure to dioxins (2,3,7,8-TCDD-TEQ), and vinyl chloride, and primarily to vinyl chloride by the inhalation pathway (Table C-10a). The total estimated cancer risk for exposure to all chemicals by all pathways is within the acceptable risk range of $1\text{E-}06$ to $1\text{E-}04$ established in USEPA (1994) guidance. No noncancer hazard estimates exceed the acceptable hazard quotient (HQ) level of one (USEPA, 1994), and the calculated hazard index (HI) for exposure to all chemicals is below 1 (Table C-10b).

All cancer risk estimates that exceed $1\text{E-}06$ for potential residential use of LHAAP-35C(53) are associated with exposure to dioxins (2,3,7,8-TCDD-TEQ), and primarily by the soil ingestion pathway (Table D-9a). No noncancer hazard estimates exceed the acceptable hazard quotient (HQ) level of one, and the calculated hazard index (HI) for exposure to all chemicals is below 1 (Table D-9b).

Groundwater concentrations associated with human health risk in the industrial risk assessment (Jacobs, 2003) were either not detected in additional groundwater sampling performed by Shaw in 2004 and 2005 (see **Sections 2.0** and **3.0**) or were below MCLs and, thus, pose no unacceptable risk to a potential resident.

5.0 Conclusions

The baseline risk assessment for LHAAP-48 and LHAAP-35C(53) (**Appendix C** and **D**, respectively) indicate that cancer risk and noncancer HI posed by the soil to a hypothetical resident are within the acceptable range established by the USEPA, and no further action is necessary for soil at LHAAP-48 and LHAAP-35C(53) (USEPA, 1994).

The industrial risk assessment (Jacobs, 2003) for a future maintenance worker, however, showed unacceptable risk and hazard at LHAAP-48 due to elevated concentrations of thallium and dioxins in the groundwater. Additional groundwater sampling conducted at LHAAP-48 in May 2005 indicated that elevated concentrations of dioxins/furans and metals were due to the high turbidity of the groundwater samples. For example, the maximum chromium concentration of 2,510 µg/L was observed in the unfiltered groundwater sample collected from LHSMW63 but was not detected in the filtered sample. Although the chromium concentration observed in LHSMW62 had a concentration of 715 µg/L in the unfiltered sample, the filtered sample indicated an almost two-fold reduction in concentration (379 µg/L), indicative of turbidity and the possible attachment of chromium to particulates within the sample. The chromium detected in groundwater at these wells was shown to be associated with stainless steel construction material (**Section 2.2**), and was likely the result of corrosion of the stainless steel screen. VOCs such as tetrachloroethene and TCE that were detected at very low levels (Jacobs, 2003), either were not detected or were detected at very low concentrations below MCLs. Perchlorate was not detected in any of the samples.

At LHAAP-35C(53), unacceptable non-cancer hazard was caused by thallium. During the 2005 sampling performed by Shaw (see **Section 3.0**), thallium was detected at concentrations below the MCL. Other metals such as arsenic, lead, and chromium were detected above MCLs in the unfiltered sample; however, in most cases the concentrations were below the detection limits or MCLs in the filtered samples, or marginally exceeded the MCLs, indicating association of these metals with particulates. Perchlorate was not detected in any of the samples and VOCs that were detected at low concentrations in previous sampling rounds either were not detected or were detected at very low levels below the MCLs.

6.0 Risk Management

Although the total cancer risk estimates to a hypothetical resident at both LHAAP-48 or LHAAP-35C(53) are within the acceptable range of $1\text{E-}06$ to $1\text{E-}04$, estimated risks associated with dioxins and vinyl chloride exceed $1\text{E-}06$.

The total cancer risk from exposure to vinyl chloride at LHAAP-48 was estimated using one sample among 48 that contained a detected concentration. Use of the only detected concentration, $4.97\text{E-}01$ mg/kg located at SUMP099, as representative of the entire LHAAP-48 site represents a conservative overestimation of vinyl chloride cancer risk. As required by Risk Reduction Standard 3 rules, a remediation level of $1.87\text{E-}01$ mg/kg was calculated for vinyl chloride using equation provided in TCEQ (1998) guidance, which corresponds to a target risk level of $1\text{E-}06$ (**Table 6-1a**). This remediation level is exceeded in samples taken near SUMP099 (Table C-2, Figure C-1). It is unlikely that a hypothetical resident would establish a residence at this location among all others at LHAAP-48, and, if that were to occur, the total risk associated with soil exposure would be within the acceptable range.

The total cancer risk from exposure to dioxins at LHAAP-48 was estimated using the maximum 2,3,7,8-TCDD TEQ concentration calculated as described in Section 2.4 of **Appendix C**. Use of the maximum detected concentration, $1.55\text{E-}05$ mg/kg located at SUMP094, as representative of the entire LHAAP-48 site represents a conservative overestimation of dioxin cancer risk.

A remediation level of $3.6\text{E-}06$ mg/kg was calculated for 2,3,7,8-TCDD using Risk Reduction Standard 3 equations provided in TCEQ (1998) guidance, which corresponds to a target risk level of $1\text{E-}06$ (**Table 6-1a**). This remediation level is exceeded in samples at six locations, 48SB01, SUMP094, SUMP095, SUMP098, SUMP100, and WRSUMP003 (Table C-2, Figure C-1). If a hypothetical resident were to establish a residence at any of these locations, the total risk associated with soil exposure would be within the acceptable range. In the unlikely event that the residence was located near SUMP098 and SUMP099, where both vinyl chloride and dioxins were detected, the total cancer risk would still be well within the acceptable range.

Because the concentrations of all chemicals that exceed a risk level of $1\text{E-}06$ do not correspond to a total cancer risk above the upper limit of the acceptable range ($1\text{E-}04$), a risk management approach to take no further action at LHAAP-48 meets the Risk Reduction Standard 3 requirement that the cumulative excess cancer risk to exposed populations (including sensitive subgroups) shall not be greater than one in 10,000 [30 TAC §335.563(b)].

The total cancer risk from exposure to dioxins at LHAAP-35C(53) was estimated using the maximum 2,3,7,8-TCDD TEQ concentration calculated as described in Section 2.4 of

Appendix D. Use of the maximum detected concentration, 3.04E-05 mg/kg located at 35CSB01, as representative of the entire LHAAP-35C(53) site represents a conservative overestimation of dioxin cancer risk.

This maximum concentration exceeds the remediation level for dioxins (**Tables 6-1a** and **6-1b**) only at the 35CSB01 location, (Table D-2, Figure D-1). In the unlikely event that the residence was located at 35CSB01, the total cancer risk would be within the acceptable range.

Because the concentration of the only chemical that exceeds a risk level of 1E-06 does not correspond to a total cancer risk above the upper limit of the acceptable range (1E-04), a risk management approach to take no further action at LHAAP-35C(53) meets the Risk Reduction Standard 3 requirement that the cumulative excess cancer risk to exposed populations (including sensitive subgroups) shall not be greater than one in 10,000 [30 TAC §335.563(b)].

Table 6-1a
TCEQ Risk Reduction Standard 3
Medium Specific Concentration for Soil - Residential Land-Use Scenario
Cancer Risk from Exposure to Chemicals in Soil at
LHAAP-48 and LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

CARCINOGENIC EFFECTS

Chemical Name	Weight of Evidence	Ingestion	Inhalation	Dermal	Relative Dermal		Molecular Diffusivity, Di (cm ² /s)	Henry's Law Constant, H (atm-m ³ /mol)	Organic Carbon Partition Coefficient Koc (cm ³ /g)	Effective Diffusivity Dei (cm ² /s)	Soil-Water Partition	Soil-Air Partition			Inhalation MSC (mg/kg)	Ingestion MSC (mg/kg)	Dermal MSC (mg/kg)	Soil MSC (mg/kg)
		Slope Factor SFo 1/(mg/kg-day)	Unit Risk Factor, URF 1/(ug/m3)	Slope Factor SFd 1/(mg/kg-day)	GI Absorption Factor, ABS.gi (unitless)	Absorption Factor, ABS.d (unitless)					Coefficient Kd (cm ³ /g)	α (cm ² /s)	Partition Coefficient Kas (cm ³ /g)	Volatilization Factor, VF m ³ /kg				
2,3,7,8-TCDD-TEQ (Dioxin) ^a	ND	1.50E+05	4.29E+01	3.00E+05	5.00E-01	3.00E-02	4.70E-02	3.59E-05	2.40E+07	3.32E-02	4.80E+05	2.07E-11	3.06E-09	2.69E+08	1.44E-02	4.27E-06	2.30E-05	3.60E-06
Vinyl chloride ^b	A	1.50E+00	8.80E-06	1.50E+00	1.00E+00	0.00E+00	1.06E-01	8.52E-02	1.10E+01	7.50E-02	2.19E-01	5.73E-02	1.59E+01	1.21E+03	3.34E-01	4.27E-01	NA	1.87E-01

Table 6-1b
TCEQ Risk Reduction Standard 3
Medium Specific Concentration for Soil - Residential Land-Use Scenario
Noncancer Hazard from Exposure to Chemicals in Soil at
LHAAP-48 and LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

NON-CARCINOGENIC EFFECTS

Chemical Name	Ingestion	Inhalation	Dermal	Relative Dermal														Applicable	
	Reference	Reference	Reference	GI Absorption	Absorption	Molecular	Henry's Law	Organic Carbon	Effective	Soil-Water Partition		Soil/air Partition	Volatilization	Inhalation	Ingestion	Dermal	Soil	Soil	
	Dose, RfDo	Conc., RfC	Dose, RfDd	Factor, ABS.gi	Factor, ABS.d	Diffusivity, Di	Constant, H	Partition Coefficient,	Diffusivity,	Coefficient, Kd	α	Coefficient, Kas	factor, VF	MSC	MSC	MSC	MSC	MSC	
	(mg/kg-day)	(mg/m3)	(mg/kg-day)	(unitless)	(unitless)	(cm²/s)	(atm-m³/mol)	Koc (cm³/g)	Dei (cm²/s)	(cm³/g)	(cm²/s)	(cm³/g)	m3/kg	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
2,3,7,8-TCDD-TEQ (Dioxin) ^a	ND	ND	ND	5.00E-01	3.00E-02	4.70E-02	3.59E-05	2.40E+07	3.32E-02	4.80E+05	2.07E-11	3.06E-09	2.69E+08	NA	NA	NA	NA	3.60E-06	
Vinyl chloride ^b	3.00E-03	1.00E-01	3.00E-03	1.00E+00	0.00E+00	1.06E-01	8.52E-02	1.10E+01	7.50E-02	2.19E-01	5.73E-02	1.59E+01	1.21E+03	1.26E+02	8.23E+02	NA	1.09E+02	1.87E-01	

Notes and Abbreviations:

^a Applicable Soil MSC applies to soil at both LHAAP-48 and LHAAP-35C(53).

^b Applicable Soil MSC applies to soil at LHAAP-48 only.

ug/m³ micrograms per cubic meter
atm-m³/mol atmosphere cubic meters per mole
cm²/s centimeter square per second
cm³/g cubic centimeters per gram
mg/kg milligrams per kilogram
m³/kg cubic meters per kilogram
MSC medium specific concentration
ND no data
RME reasonable maximum exposure
URF unit risk factor

7.0 References

Jacobs Engineering Group, Inc. (Jacobs), 2002a, *Final Remedial Investigation Report, Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Volume 1: Report, Longhorn Army Ammunition Plant, Karnack, Texas*, January.

Jacobs, 2002b, *Draft Feasibility Study, Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunder's Branch, Central Creek, and Caddo Lake*, August.

Jacobs, 2003, *Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunder's Branch, Central Creek, and Caddo Lake, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee*, June.

Shaw Environmental, Inc. (Shaw), 2004, *Final Work Plan Groundwater Data Gaps Investigation Groups 2 and 4, Longhorn Army Ammunition Plant, Karnack, Texas*, February.

Shaw, 2005, *Draft Final Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas*, May.

Texas Commission on Environmental Quality (TCEQ) 1998, Interoffice Memorandum from Ronald R. Pedde to Remediation Division Staff regarding implementation of the existing risk reduction rules (a.k.a. TNRCC Consistency Memorandum), July.

TCEQ, 2004, *Texas Risk Reduction Rules* (30TAC§335) as updated through March 2006.

U.S. Environmental Protection Agency (USEPA), 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-0202, March.

USEPA, 1994, *National Oil and Hazardous Substances Pollution Contingency Plan*, 40 Code of Federal Regulations Part 300, 59 Federal Register 47384, October 10.

Van den Berg, M., Birnbaum, L., Bosveld, A.T.C., Brunstrom, B., Cook, P., Feeley, M., Giesy, J.P., Hanberg, A., Hasegawa, R., Kennedy, S.W., Kubiak, T., Larsen, J.C., van Leeuwen, F.X.R., Liem, A.K.D., Nolt, C., Peterson, R.E., Poellinger, L., Safe, S., Schrenk, D., Tillitt, D., Tysklind, M., Younes, M., Waern, F. and Zacharewski, T., 1998, *Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife*, Environmental Health Perspectives 106(12):775-792.

Appendix A
Groundwater Sampling Forms
LHAAP-48



Sample Collection Log

00043626

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: 48-091304-60
48-091304-KE

Location Code: 48WW01

Sample Number: L0001-48WW01

Sample Name: L0001-48WW01-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip:

QC Partners:

(TB)

N/A

(ER)

N/A

(FB)

N/A

Task: GW DATA GAPS AUG04

Collection Date: 9/13/04

Collection Time: 1345

Start Depth: 22.94

End Depth: 22.94

Sample Matrix: WATER
D. Holderfield

Sample Team: A. Willmore

ERPIMS Values:

Sacode:

Lot Control#:

Containers
Analytical Suite Flt Frtn Qty Size Units Type

METALS W	N	A	1	500	ml	HDPE	HNO ₃
PERC	N	B	1	1	l	HDPE	
Dioxins Furans	N	C	2	1	l	Amb Glass	

Groundwater Information:

Measured Well Depth: 57.64

Depth To Water: 22.32

Comments:

Sketch Location:

Logged BY / Date: [Signature] 9/13/04

Reviewed BY / Date: [Signature] 9/13/04



Sample Collection Log

00043627

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 48WW01

Sample Number: L0001-48WW01

Sample Name: L0001-48WW01-00-QC

Sampling Method: BA

Sample Type: GW

Sample Purpose: FD

Sampling Equip:

Bladder pump

QC Partners:

(TB)

N/A

(ER)

N/A

(FB)

N/A

RFA / COC Number:

48 - 091304 - C0

48 091304 - RE

Task: GW DATA GAPS AUG0

Collection Date: 9/13/04

Collection Time: 1345

Start Depth: 22.94

End Depth: 22.94

Sample Matrix: WATER

Sample Team: D. Holdenfield
A. Willmore

Containers

Analytical Suite Flt Frtn Qty Size Units Type

Dioxins/Furans	N	A	2	1	P	Amb. Glass
METALS W	N	B	1	500	ml	HDPE
PERC	N	C	1	1	P	HDPE

ERPIMS Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 57.04

Depth To Water: 22.32

Comments:

Sketch Location:

Logged BY / Date: D. Holdenfield 9/13/04

Reviewed BY / Date: D. Holdenfield 9/13/04

Sample Collection Log

00043628

Page 2 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 48WW01

Sample Number: L0001-48WW01

+ L0001-48WW01-QC
(FD)

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
Sample:	1400 DHA 9/13/04	22.94	4.5	6.51	1.031	9.7	0.84	22.90	3.3

Logged BY / Date: Dan Hobbs 9/13/04

Reviewed BY / Date: Dan Hobbs 9/13/04



GROUNDWATER SAMPLING FORM

00043629

Sheet 1 of 2

Operable Unit/Site ID: 48

Project Name/#: CHAMP

Weather: CLOUDY 80s to 90s

Sampling location ID: 48NW01

Sample ID: 48NW01

Collection Time/Date:

Pump Installation

Pump installation crew: A. Willmore, D. Holterfield

PID/FID reading (well head/background): 0.0

Casing diameter (inches): 4"

Total well Depth (ft. BTOC): 57.14

Initial (pre-installation) DTW/time: 22.32

Final (after pump priming) DTW/time:

Free product (circle): LNAPL / DNAPL

Volume of water removed during priming (mL):

Discharge tube length (ft.): 60'

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = 22.42 psi

Installation date/beginning time: 9/13/04 12:03

Installation date/completion time: 9/13/04 12:04

Screen Interval (ft. BTOC): 47.14 to 57.14

Pump intake depth (ft BTOC): 52.41

Post-installation DTW/time: 21.80 12:06

Max. sustainable pump rate (mL/min):

Appearance of product:

Discharge tube diameter (3/8" or 1/4"): 3/8"

Inlet reducer used (Y/N): No

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: A. Willmore, D. Holterfield

Purge date/beginning time: 9/13/04 12:25

Initial (pre-purging) DTW (ft. BTOC): 22.32

Calculated tubing + pump volume: NA

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = 22.42 psi

PID/FID reading (well head/background): 0.0

Purge date/completion time: 9/13/04 12:26 13:35

Final (post-purging) DTW (ft. BTOC): 22.41

No. of tubing + pump volumes purged:

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	30	30.21	26						26
Refill Setting	10	14	15						15
Discharge Setting	5	6	5						5
Flow rate (mL/min)	—	50	110						110

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
12:25	22.41	50	0.1	21.44	0.380	6.48	131.1	6.23	9.4
12:30	22.49	110	0.3	22.41	1.016	6.56	138.2	3.53	21.4
12:35	22.69	110	0.4	22.42	1.053	6.51	139.7	2.26	19.9
12:40	22.91	110	0.6	22.03	1.050	6.61	138.5	1.71	19.4
12:45	22.93	110	0.8	22.42	1.048	6.51	122.0	1.53	19.7
12:50	22.94	110	1.0	22.35	1.050	6.52	56.0	1.49	19.8
12:55	22.94	110	1.2	22.56	1.046	6.52	50.0	1.15	19.3
13:00	22.94	110	1.3	22.63	1.046	6.52	34.4	1.01	19.1

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043631

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

48-091404-KF

RFA / COC Number: 48-091404-02

Location Code: LHSMW62

Sample Number: L0001-LHSMW6

Sample Name: L0001-LHSMW62-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip: 1" PVC Bailer

QC Partners:

(TB)

(ER)

(FB)

Task: GW DATA GAPS AUG0

Collection Date: 9/13/04

Collection Time: 16:52

Start Depth: 21.45

End Depth: 21.33

Sample Matrix: WATER

Sample Team: A. Willmore, B. Ansley

ERPIMS Values:

Sacode:

Lot Control#:

Containers

Analytical Suite Flt Frtn Qty Size Units Type

METALS W	N	A	1	500	ml	HDPE	FLNa
PERC	N	B	1	1	l	HDPE	
Dioxins Furans	N	C	2	100	ml	AmB	CLASS

Groundwater Information:

Measured Well Depth: 29.45

Depth To Water: 20.91

Comments:

Had to bail well due to slow recharge characteristics

Sketch Location:

Logged BY / Date:

9/14/04

Reviewed BY / Date:

9/14/04

Sample Collection Log

00043632

Page 2 of 2

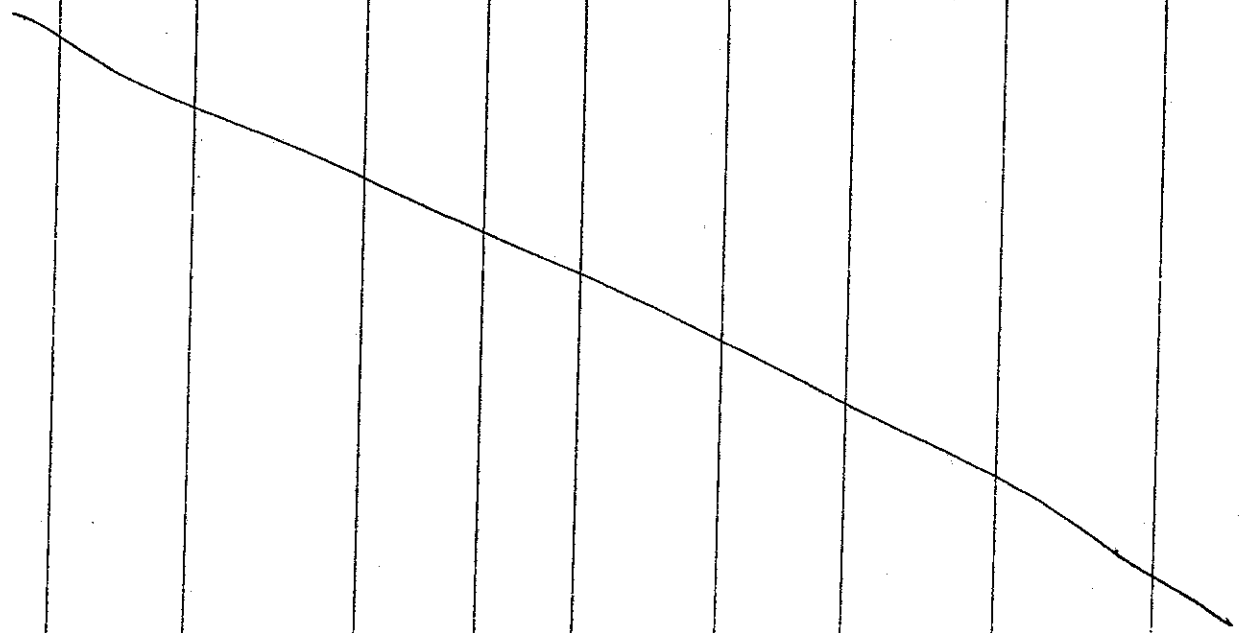
845714 LONGHORN AAP

Manager: Praveen Srivastav


Location Code: LHSMW62

Sample Number: L0001-LHSMW6

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
									
Sample:	10:59	21.73	81.3	5.32	3.143	20.4	1.04	23.74	10 gal

Logged BY / Date:


9/13/04

Reviewed BY / Date:


9/14/04



GROUNDWATER SAMPLING FORM

00043633

Sheet 1 of 2

Operable Unit/Site ID: 48
Project Name/ID: LHAAP
Weather: CLEAR, 80s to 90s

Sampling location ID: 48-LH6M02
Sample ID: LH6M02
Collection Time/Date: 9/13/01 16:53

Pump Installation

Pump installation crew: A. Willmore, D. Hottel
PID/FID reading (well head/background): 0.0
Casing diameter (inches): 4"
Total well Depth (ft. BTOC): 29.45
Initial (pre-installation) DTW/time: 20.41 9:02 8:48
Final (after pump priming) DTW/time: 9:01
Free product (circle): LNAPL / DNAPL
Volume of water removed during priming (mL):
Discharge tube length (ft.): 60'
Pneumatic Controller Tuning:
Initial air pressure = H (ft.) X 0.43 = 10.51 psi

Installation date/beginning time: 9/13/01 8:58
Installation date/completion time: 9/13/01 8:59
Screen Interval (ft. BTOC): 19.45 to 29.45
Pump intake depth (ft. BTOC): 24.45 9:03
Post-installation DTW/time: 20.76
Max. sustainable pump rate (mL/min): 200
Appearance of product: ---
Discharge tube diameter (3/8" or 1/4"): 3/8"
Inlet reducer used (Y/N): No

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: A. Willmore, D. Hottel
Purge date/beginning time:
Initial (pre-purging) DTW (ft. BTOC):
Calculated tubing + pump volume: NA
Pneumatic Controller Tuning:
Initial air pressure = H (ft.) X 0.43 = 10.51 psi

PID/FID reading (well head/background): 0.0
Purge date/completion time: 9/13/01
Final (post-purging) DTW (ft. BTOC):
No. of tubing + pump volumes purged:

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>17</u>	<u>17</u>							<u>17</u>
Refill Setting	<u>10</u>	<u>11.4</u>							<u>11.4</u>
Discharge Setting	<u>5</u>	<u>4.6</u>							<u>4.6</u>
Flow rate (mL/min)	<u>200</u>	<u>105</u>							<u>105</u>

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
<u>9:27</u>	<u>21.27</u>	<u>105</u>	<u>0.2</u>	<u>21.78</u>	<u>3.163</u>	<u>5.29</u>	<u>75.3</u>	<u>1.26</u>	<u>108.6</u>
<u>9:32</u>	<u>21.43</u>	<u>105</u>	<u>0.3</u>	<u>21.93</u>	<u>3.169</u>	<u>5.29</u>	<u>74.4</u>	<u>1.19</u>	<u>100.9</u>
<u>9:37</u>	<u>21.51</u>	<u>105</u>	<u>0.4</u>	<u>22.17</u>	<u>3.171</u>	<u>5.30</u>	<u>73.6</u>	<u>1.23</u>	<u>73.9</u>
<u>9:42</u>	<u>21.52</u>	<u>105</u>	<u>0.5</u>	<u>22.41</u>	<u>3.176</u>	<u>5.30</u>	<u>76.3</u>	<u>1.04</u>	<u>71.4</u>
<u>9:47</u>	<u>21.53</u>	<u>105</u>	<u>0.7</u>	<u>22.52</u>	<u>3.174</u>	<u>5.31</u>	<u>77.7</u>	<u>1.04</u>	<u>64.5</u>
<u>9:52</u>	<u>21.54</u>	<u>105</u>	<u>0.9</u>	<u>22.51</u>	<u>3.168</u>	<u>5.31</u>	<u>76.4</u>	<u>0.98</u>	<u>61.4</u>
<u>9:57</u>	<u>21.65</u>	<u>105</u>	<u>1.0</u>	<u>22.71</u>	<u>3.162</u>	<u>5.31</u>	<u>74.1</u>	<u>0.95</u>	<u>42.2</u>
<u>10:02</u>	<u>21.75</u>	<u>105</u>	<u>1.2</u>	<u>22.79</u>	<u>3.164</u>	<u>5.31</u>	<u>73.9</u>	<u>0.91</u>	<u>56.2</u>



GROUNDWATER SAMPLING FORM

00043634

Sheet ___ of ___

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C) $\pm 10\%$	Electrical Conductivity (uMhos/cm) $\pm 3\%$	pH ± 0.1	Eh (mv) ± 10	DO (mg/L) $\pm 10\%$	Turbidity (NTU) $\pm 10\%$
10:03	21.91	105	1.4	23.29	3.143	5.32	99.3	0.87	35.0
10:17	21.98	105	1.8	23.36	3.140	5.32	79.5	0.86	34.5
10:17	22.03	105	1.7	23.47	3.114	5.33	80.2	0.84	29.5
10:22	22.09	105	1.9	23.82	3.102	5.33	80.4	0.83	26.3
10:29	22.14	105	2.0	23.77	3.101	5.33	80.5	0.80	22.7
Must Bail !!									

Sampling

Sampling beginning time: _____

Sampling completion time: _____

Water Quality Parameter Measurements									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
16:57	21.73	100	10 gal	23.74	3.143	5.32	81.3	1.04	20.4

Sample Information

Sample ID: LHSM C2
Duplicate sample collected (Y/N): Y
Split sample collected (Y/N): _____
COC No(s): _____

Sample collection date/time: _____
Duplicate sample ID: _____
Split sample ID: _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043635

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number:

Location Code: LHSMW63

Sample Number: L0001-LHSMW6

Sample Name: L0001-LHSMW63-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip:

QC Partners:

(TB)

(ER)

(FB)

Task: GW DATA GAPS AUG04

Collection Date: 9/13/04

Collection Time:

Start Depth:

End Depth:

Sample Matrix: WATER

Sample Team:

Containers

Analytical Suite Flt Frtn Qty Size Units Type

METALS-W	N	A	1	500	ml	HDPE	HNO ₃
PERC	N	B	1	1	l	HDPE	
DICHLOROMETHANE	N	C	2	1	l	HDPE	

ERPIMS Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 22.12

Depth To Water: 21.60

Comments:

0845- well only 6 inches water Bailed Dry - ~1 quart reddish brown silty water in appearance

No sample collected

Sketch Location:

Logged BY / Date:

Reviewed BY / Date:

Reviewed BY / Date:

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
			Bail Dry	0850		~1 quart			
				Return @ 1030		DTW = 22.02			
				1340		DTW = 22.00			
				1550		DTW = 22.00			
				9/14/04 0845		DTW = 21.99			
				No sample collected					

[illegible]

10-
20

Sampling

Sampling beginning time: _____

Sampling completion time:

Water Quality Parameter Measurements

[illegible]

Sample Information

Sample ID: _____

Sample collection date/time:

Duplicate sample collected (Y/N):

Duplicate sample ID: _____

Split sample collected (Y/N):

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: 22.12 Bail Dry Return @ 1030 DTW = 22.02
21.60 Return @ 1340 DTW = 22.00
00.52' water (6" water) Return @ 1450 DTW = 22.00

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043639

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number:

48-091404-KE

48-091404-CO

Location Code: LHSMW64

Sample Number: L0001-LHSMW64

Sample Name: L0001-LHSMW64-00

Sampling Method: BA + MS, MSD

Sample Type: GW

Sample Purpose: REG

Sampling Equip:

PVC Disposable bailer

QC Partners:

(TB)

N/A

(ER)

N/A

(FB)

N/A

Task: GW DATA GAPS AUG0

Collection Date:

9/13/04

Collection Time:

1540

Start Depth:

21.33

End Depth:

N/A

Sample Matrix:

WATER

Sample Team:

W. Critz / M. Martin

ERPIMS Values:

Sacode:

Lot Control#:

Containers
Analytical Suite Flt Frtn Qty Size Units TypeHNO₃

METALS W	N	A	1	500	ml	HDPE
PERC	N	B	1	1	l	HDPE
Dioxins Furans	N	C	2	1	l	Ambr Glass

HNO₃

Groundwater Information:

Measured Well Depth:

27.75

Depth To Water:

21.33

Comments:

Bailed Well Dry (Approx 5 gal.) Returned and sampled well. MS/MSD also collected from this well

Sketch Location:

Logged BY / Date:

W. Critz 9/13/04

Reviewed BY / Date:

D. Smith 9/14/04

Sample Collection Log

00043640

Page 2 of 2

845714 LONGHORN AAP
Manager: Praveen Srivastav

Location Code: LHSMW64
Sample Number: L0001-LHSMW6

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
See Env Sampling Form LHSMW64									
Bailed Dry and Sampled									

Logged BY / Date:

W. S. Citz 9/13/04

Reviewed BY / Date:

P. Srivastav 9/14/04



GROUNDWATER SAMPLING FORM

00043641

Sheet 1 of 2

Operable Unit/Site ID: Aeq 48 Longhorn NW
Project Name/ID: Longhorn AAP
Weather: _____

Sampling location ID: LHS MLW 004
Sample ID: LHS MLW 004
Collection Time/Date: 9-13-04 / 1540

Pump Installation

Pump installation crew: M. Martinez / L. C. C. C.
PID/FID reading (well head/background): 0.0/0.0
Casing diameter (inches): 4"
Total well Depth (ft. BTOC): 27.75
Initial (pre-installation) DTW/time: 21.33 / 0900
Final (after pump priming) DTW/time: 21.15 / 0915 21.45
Free product (circle): LNAPL / DNAPL 0940
Volume of water removed during priming (mL): _____
Discharge tube length (ft.): _____

Installation date/beginning time: 9-13-04 / 0913
Installation date/completion time: 9-13-04 / 0944
Screen Interval (ft. BTOC): 17.75 to 27.75
Pump intake depth (ft. BTOC): 25'
Post-installation DTW/time: 21.15 / 0915
Max. sustainable pump rate (mL/min): ~1A
Appearance of product: C/A
Discharge tube diameter (3/8" or 1/4"): 3/8
Inlet reducer used (Y/N): NO

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: M. Martinez / L. C. C. C.
Purge date/beginning time: 09-13-04 / 0930
Initial (pre-purging) DTW (ft. BTOC): 21.33
Calculated tubing + pump volume: _____ NA

PID/FID reading (well head/background): 0.0/0.0
Purge date/completion time: 09-13-04 / 0930
Final (post-purging) DTW (ft. BTOC): ~1A
No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>20</u>	<u>20</u>							
Refill Setting	<u>12.0</u>	<u>13.0</u>							
Discharge Setting	<u>3.0</u>	<u>2.0</u>							
Flow rate (mL/min)	<u>180</u>	<u>100</u>							

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0950	21.87	100	0	21.47	0.323	5.84	344.8	1.22	137.3
0955	22.01	100	0.5	21.55	0.324	5.87	322.0	1.11	124.8
1000	22.18	100	1.0	21.57	0.325	5.85	302.1	0.97	109.8
1005	22.26	100	1.5	21.75	0.325	5.89	281.0	0.88	96.6
1010	22.34	100	2.0	21.80	0.325	5.87	287.2	0.87	89.7

Hand Drill



Sample Collection Log

00043643

48

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW65

Sample Number: L0001-LHSMW6

Sample Name: L0001-LHSMW65-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip: _____

Task: GW DATA GAPS AUG0

Collection Date: _____

Collection Time: _____

Start Depth: _____

End Depth: _____

Sample Matrix: WATER

9/13/04 W. Critz M. Martinez
Sample Team: 9/14/04 K. Smith, J. Rodriguez

ERPIMS Values:

Sacode: _____

Lot Control#: _____

QC Partners:

(TB)

(ER)

(FB)

Containers

Analytical Suite Flt Frtn Qty Size Units Type

METALS W	N	A	1	500	ml	HDPE
PERC	N	B	1	12	L	HDPE
DO NOT FILL	N	C	2	1	L	AMBER GLASS

Groundwater Information:

Measured Well Depth: _____

Depth To Water: _____

Comments:

Return 0835 9/14/04 DTW = 20.41 TD = 20.45
Not enough to sample - No sample collected.

Sketch Location: _____

Logged BY / Date: _____

Reviewed BY / Date: _____

Reviewed BY / Date:

[illegible]

00043646

Sheet 2 of 2

10-e
20

Sampling beginning time: _____ Sampling completion time: _____

Sample Information

Sample collection date/time: 2/8
Duplicate sample ID: 2/11
Split sample ID: 2/11

Comments:	20.43	19.93	0.5	0.325	0.9
	TD	OTW	WC	1LV	3LV
Hand Bad well					

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043648

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number:

Location Code: LHSMW66

Sample Number: L0001-LHSMW6

Sample Name: L0001-LHSMW66-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip:

QC Partners:

(TB)

(ER)

(FB)

Task: GW DATA GAPS AUG04

Collection Date:

Collection Time:

Start Depth:

End Depth:

Sample Matrix: WATER

Sample Team:

Containers

Analytical Suite Flt Frtn Qty Size Units Type

METALS W	N	A	1	500	ml	HDPE	H103
PERC	N	B	1	1	l	HDPE	
Phenol-Picric	N	C	1	1	l	Amb. Glass	

ERPIMS Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 20.45

Depth To Water: 19.97

Comments:

Bailed well dry 0930 ~1 quart

No sample collected

Sketch Location:

Logged BY / Date: K. Everett 9/13/04

Reviewed BY / Date:

Reviewed BY / Date:



GROUNDWATER SAMPLING FORM

00043650

Sheet 1 of 2

Needs Lock

Operable Unit/Site ID: _____

Project Name/#: LHAAPWeather: hot clearSampling location ID: Site 48 LHSMN66

Sample ID: _____

Collection Time/Date: No sample - well Dry

Pump Installation

Pump installation crew: R. Everett, J. RodriguezInstallation date/beginning time: 9/13/04PID/FID reading (well head/background): 0.1 / 3.4 (Bg, d)

Installation date/completion time: _____

Casing diameter (inches): 4" PVC

Screen Interval (ft. BTOC): _____ to _____

Total well Depth (ft. BTOC): 20.45

Pump intake depth (ft BTOC): _____

Initial (pre-installation) DTW/time: 19.97

Post-installation DTW/time: _____

Final (after pump priming) DTW/time: NA

Max. sustainable pump rate (mL/min): _____

Free product (circle): LNAPL / DNAPL

Appearance of product: _____

Volume of water removed during priming (mL): _____

Discharge tube diameter (3/8" or 1/4"): 3/8Discharge tube length (ft.): 30'Inlet reducer used (Y/N): N

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: _____

PID/FID reading (well head/background): _____

Purge date/beginning time: _____

Purge date/completion time: _____

Initial (pre-purging) DTW (ft. BTOC): _____

Final (post-purging) DTW (ft. BTOC): _____

Calculated tubing + pump volume: NA

No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
	<u>Bail Dry</u>			<u>0930</u>	<u>~1 quart</u>				
	<u>Return</u>			<u>1035</u>	<u>DTW = 20.38'</u>				
				<u>1345</u>	<u>DTW = 20.33</u>				
				<u>1600</u>	<u>DTW = 20.32</u>				
			<u>9/14/04</u>	<u>0825</u>	<u>DTW = 20.32</u>				
<u>No Samples Collected</u>									

1.0211 qt
1.0845 gal
13
65
65

Sample Collection Log

00043653

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: 48WW01

Sample Number: 48WW01-MAY05

Sample Name: 48WW01-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: QED BLADDER pump

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5-12-05

Collection Time: 1555

Start Depth: 21.77

End Depth: 21.77

Sample Matrix: WATER

Sample Team: JMW + M. Ben

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000 ³⁰⁰ mL		HDPE
METALS-DIS	N	C	1	1000 ³⁰⁰ mL		HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass
PERC	N	F	1	1	L	HDPE

Groundwater Information:

Measured Well Depth: 60

Depth To Water: 20.42

Comments:

Sketch Location:

Logged BY / Date: _____

Reviewed BY / Date: _____

Sample Collection Log

00043654

Page 2 of 2

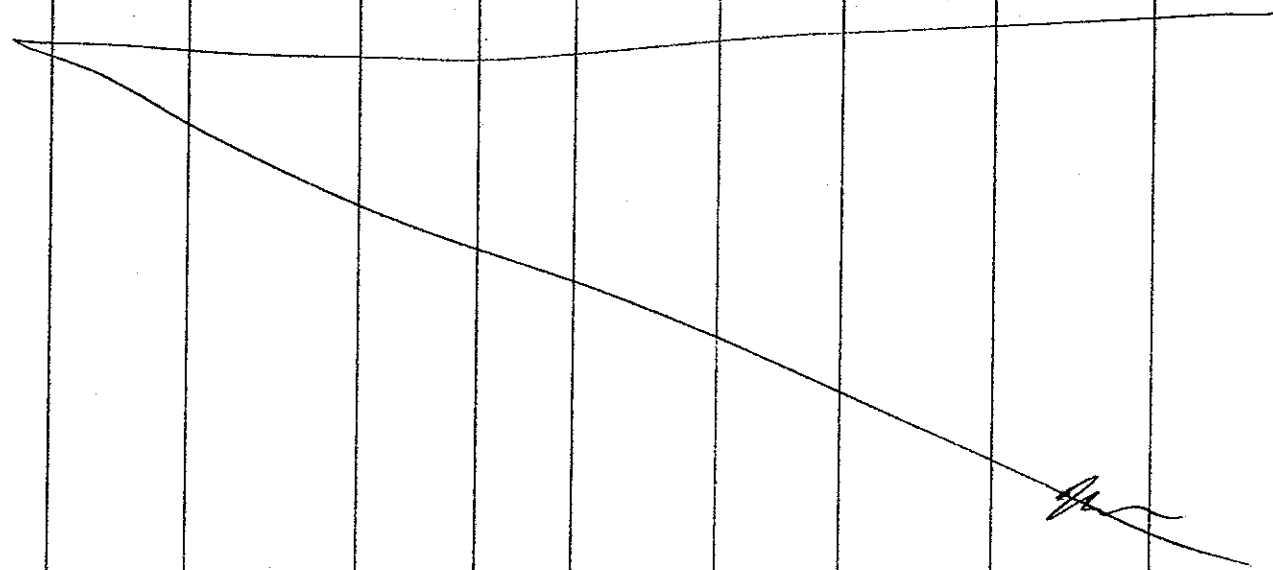
845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 48WW01

Sample Number: 48WW01-MAY05

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal) - Liter (L)
6/1	1555	21.77	27.2	6.37	0.754	6.2	1.76	20.69	25.1 L
									
Sample:	1650	21.77	23.8	6.37	0.740	3.9	1.54	20.78	26.1 L

Logged BY / Date: _____

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043655

Sheet 1 of 6

Operable Unit/Site ID: 48 Sampling location ID: 48WW01
Project Name/ID: LHAAP Sample ID: 48WW01-MAY05
Weather: Clear, slight breeze, high 80 low 90s Collection Time/Date: _____

Pump Installation

Pump installation crew: J. VALLEY / M. Brown Installation date/beginning time: _____
PID/FID reading (well head/background): 0-0 Installation date/completion time: _____
Casing diameter (inches): 4" Screen Interval (ft. BTOC): 8' 50" to 60'
Total well Depth (ft. BTOC): 60 Pump intake depth (ft. BTOC): 55'
Initial (pre-installation) DTW/time: 20.42 Post-installation DTW/time: _____
Final (after pump priming) DTW/time: 20.42 Max. sustainable pump rate (mL/min): _____
Free product (circle): LNAPl / DNAPL Appearance of product: NA
Volume of water removed during priming (mL): _____ Discharge tube diameter (3/8" or 1/4"): 3/8
Discharge tube length (ft.): 58 Inlet reducer used (Y/N): No

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = 23.65 psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>30</u>	<u>25</u>	<u>25.5</u>	<u>30</u>	<u>30</u>	<u>30</u>	<u>30</u>	<u>30</u>	
Refill Setting	<u>10</u>	<u>20</u>	<u>13.5</u>	<u>13.1</u>	<u>13.1</u>	<u>14</u>	<u>14</u>	<u>14</u>	
Discharge Setting	<u>5</u>	<u>10</u>	<u>1.5</u>	<u>2.2</u>	<u>2.3</u>	<u>2.4</u>	<u>2.3</u>	<u>2.2</u>	
Flow rate (mL/min)	<u>200</u>	<u><50</u>	<u>100</u>	<u>900</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	

Purging

Purging/sampling crew: J. VALLEY / Mark Brown PID/FID reading (well head/background): 0.0
Purge date/beginning time: 5/11/05 1600 Purge date/completion time: 5-12-05 1555
Initial (pre-purging) DTW (ft. BTOC): 20.42 Final (post-purging) DTW (ft. BTOC): 21.77
Calculated tubing + pump volume: NA No. of tubing + pump volumes purged: 26.1 L

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = 23.65 psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
<u>1602</u>	<u>20.85</u>	<u>200</u>	<u>0.400</u>						
<u>1610</u>	<u>20.82</u>	<u><50</u>	<u>0.400</u>						
<u>1620</u>	<u>20.83</u>	<u>100*</u>	<u>0.900</u>						
<u>1633</u>	<u>21.04</u>	<u>100*</u>	<u>1.4</u>						
<u>1636</u>	<u>21.07</u>	<u>100*</u>	<u>1.9</u>						
<u>1639</u>	<u>21.11</u>	<u>100*</u>	<u>2.0</u>						
<u>1642</u>	<u>21.17</u>	<u>100*</u>	<u>2.3</u>						
<u>STOPPED FOR DAY</u>									

* Purge Rate Fluctuating while adjusting controls & thus no reading



GROUNDWATER SAMPLING FORM

00043656

Sheet 2 of 6

Water Quality Parameter Measurements (continued)

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1135	20.46	Prior	To starting	22.64	0.837	6.55	159.9	6.89	1.1
1145	20.88	90	4.50	21.21	0.843	6.84	194.5	6.80	6.3
1150	20.76	110	1.0	21.82	0.846	6.57	174.4	6.04	1.6
1200	20.95	100	2.0	22.4	0.845	6.48	170.4	4.47	1.8
1205	21.00	100	2.5	21.75	0.844	6.44	159.1	4.52	1.8
1210	21.05	100	3.0	21.73	0.841	6.44	148.0	5.23	2.4
1215	21.13	100	3.5	21.69	0.839	6.44	139.2	4.97	2.8
1220	21.20	100	4.0	21.29	0.837	6.43	130.1	4.65	3.9
1225	21.28	100	4.5	21.13	0.831	6.43	114.7	4.26	4.7
1230	21.33	100	5.0	20.87	0.830	6.43	107.0	4.12	7.0
1235	21.31	90	5.45	21.41	0.823	6.43	97.4	3.82	6.7
1240	21.38	110	5.95	21.58	0.824	6.43	94.6	3.68	9.3
1245	21.43	100	6.45	21.43	0.820	6.43	91.1	3.54	10.9

Sampling

Sampling beginning time: _____ Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: _____ Sample collection date/time: _____
 Duplicate sample collected (Y/N): _____ Duplicate sample ID: _____
 Split sample collected (Y/N): _____ Split sample ID: _____
 COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



GROUNDWATER SAMPLING FORM

00043657

Sheet 3 of 6

Operable Unit/Site ID: 48 Sampling location ID: 18W001
Project Name/ID: LHAAP Sample ID: 48W001-MAY05
Weather: Clear Sunny 90 Light Breeze Collection Time/Date: 1555 5-12-05

Pump Installation

Pump installation crew: _____ Installation date/beginning time: _____
PID/FID reading (well head/background): _____ Installation date/completion time: _____
Casing diameter (inches): _____ Screen Interval (ft. BTOC): _____ to _____
Total well Depth (ft. BTOC): _____ Pump intake depth (ft. BTOC): _____
Initial (pre-installation) DTW/time: _____ Post-installation DTW/time: _____
Final (after pump priming) DTW/time: _____ Max. sustainable pump rate (mL/min): _____
Free product (circle): LNAPL / DNAPL Appearance of product: _____
Volume of water removed during priming (mL): _____ Discharge tube diameter (3/8" or 1/4"): _____
Discharge tube length (ft.): _____ Inlet reducer used (Y/N): _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: _____ PID/FID reading (well head/background): _____
Purge date/beginning time: _____ Purge date/completion time: _____
Initial (pre-purging) DTW (ft. BTOC): _____ Final (post-purging) DTW (ft. BTOC): _____
Calculated tubing + pump volume: NA No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1250	21.42	100	6.95	21.73	0.819	6.44	84.9	3.37	10.5
1255	21.44	100	7.45	21.74	0.817	6.44	84.5	3.34	11.0
1300	21.45	100	7.95	21.74	0.815	6.44	84.6	3.26	13.4
1305	21.45	100	8.45	21.74	0.813	6.43	78.6	3.12	12.6
1310	21.49	100	8.95	21.63	0.806	6.43	74.7	3.07	10.4
1315	21.49	100	9.45	21.68	0.804	6.43	72.6	2.99	9.8
1320	21.49	100	9.95	21.89	0.802	6.42	69.7	2.88	12.5
1325	21.50	100	10.45	21.89	0.800	6.42	66.8	2.78	12.5



GROUNDWATER SAMPLING FORM

00043658

Sheet 4 of 6

Water Quality Parameter Measurements (continued)

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1330	21.52	100	10.95	21.69	0.796	6.42	63.5	2.71	9.7
1335	21.53	100	11.45	21.75	0.793	6.42	60	2.65	9.5
1340	21.54	100	11.95	21.77	0.792	6.42	58.6	2.62	9.9
1345	21.56	100	12.45	21.82	0.791	6.42	56.2	2.60	10.5
1350	21.57	100	12.95	21.66	0.788	6.41	54.4	2.60	10.3
1355	21.57	100	13.45	21.82	0.786	6.41	51.7	2.54	10.1
1400	21.57	100	13.95	21.98	0.784	6.41	49.7	2.32	10.1
1405	21.57	100	14.45	21.99	0.783	6.41	49.6	2.32	10.2
1410	21.61	110	14.95	21.87	0.779	6.40	46.6	2.25	8.4
1415	21.62	100	15.50	21.51	0.779	6.40	45.7	2.23	7.8
1420	21.61	100	16.00	21.66	0.777	6.40	45.6	2.20	7.8
1425	21.56	90	16.45	22.29	0.773	6.40	39.6	2.13	7.9
1430	21.56	100	16.95	22.3	0.773	6.40	37.9	2.10	7.2
1435	21.59	100	17.45	22.03	0.773	6.40	37.4	2.09	7.4

Sampling

Sampling beginning time: _____

Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: _____

Sample collection date/time: _____

Duplicate sample collected (Y/N): _____

Duplicate sample ID: _____

Split sample collected (Y/N): _____

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: _____

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



GROUNDWATER SAMPLING FORM

00043659

Sheet 5 of 6

Operable Unit/Site ID: 48 Sampling location ID: 48NW01
Project Name/ID: LHAA Sample ID: 48NW01-M1Y05
Weather: Clear/Sunny, 90°, slight Breeze Collection Time/Date: 1555 / 5-12-05

Pump Installation

Pump installation crew: _____ Installation date/beginning time: _____
PID/FID reading (well head/background): _____ Installation date/completion time: _____
Casing diameter (inches): _____ Screen Interval (ft. BTOC): _____ to _____
Total well Depth (ft. BTOC): _____ Pump intake depth (ft. BTOC): _____
Initial (pre-installation) DTW/time: _____ Post-installation DTW/time: _____
Final (after pump priming) DTW/time: _____ Max. sustainable pump rate (mL/min): _____
Free product (circle): LNAPL / DNAPL Appearance of product: _____
Volume of water removed during priming (mL): _____ Discharge tube diameter (3/8" or 1/4"): _____
Discharge tube length (ft.): _____ Inlet reducer used (Y/N): _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: _____ RID/FID reading (well head/background): _____
Purge date/beginning time: _____ Purge date/completion time: _____
Initial (pre-purging) DTW (ft. BTOC): _____ Final (post-purging) DTW (ft. BTOC): _____
Calculated tubing + pump volume: NA No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1440	21.59	100	18.45	21.80	0.773	6.40	36.00	2.06	6.6
1445	21.62	100	19.25	21.67	0.772	6.40	36.1	2.02	8.5
1450	21.62	100	20.52	21.52	0.768	6.39	35.6	1.99	8.8
1455	21.65	110	20.45	21.24	0.765	6.38	34.2	1.94	7.3
1500	21.69	110	20.55	21.09	0.764	6.39	33.1	1.92	8.1
1505	21.71	100	21.10	21.02	0.762	6.38	32.8	1.90	6.8
1530	21.74	100	21.6	20.88	0.759	6.38	31.1	1.87	6.7
1535	21.75	100	22.1	20.87	0.758	6.38	31.0	1.85	5.8

Sample Collection Log

00043661

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW62

Sample Number: LHSMW62-MAY

Sample Name: LHSMW62-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: PERISTALTIC Pump

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5-12-05

Collection Time: 1325

Start Depth: 19.61

End Depth: 20.25

Sample Matrix: WATER

Sample Team: JPW + M. P. Srivastav

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	500 mL	HDPE
METALS-DIS	N	C	1	1000	500 mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

Groundwater Information:

Measured Well Depth: 29.45

Depth To Water: 19.61

Comments: _____

Sketch Location: _____

Logged BY / Date: _____

Reviewed BY / Date: _____



Shaw E & I, Inc.

Sample Collection Log

00043662

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW62

Sample Number: LHSMW62-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
<i>21</i>	<i>1961</i>		<i>185.0</i>	<i>5.17</i>	<i>2.984</i>	<i>4.1</i>	<i>1.94</i>	<i>23.50</i>	
Sample:	<i>1345</i>	<i>20.25</i>	<i>206.7</i>	<i>5.12</i>	<i>3.064</i>	<i>4.4</i>	<i>2.75</i>	<i>20.23</i>	<i>5.12</i>

Logged BY / Date: _____

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043663

Sheet 1 of 2

Operable Unit/Site ID: <u>48</u>	Sampling location ID: <u>LH5MW62</u>
Project Name/ID: <u>LH AAP</u>	Sample ID: <u>LH5MW62-MAY05</u>
Weather: <u>Clear / 90°F</u>	Collection Time/Date: <u>1325 5/12/05</u>

Pump Installation

Pump installation crew: <u>DM - M. Brown</u>	Installation date/beginning time: <u>NA</u>
PID/FID reading (well head/background): <u>0.0</u>	Installation date/completion time: <u>NA</u>
Casing diameter (inches): <u>4"</u>	Screen Interval (ft. BTOC): <u>NA</u> to <u>NA</u>
Total well Depth (ft. BTOC): <u>29.45</u>	Pump intake depth (ft BTOC): <u>NA</u>
Initial (pre-installation) DTW/time: <u>19.51</u>	Post-installation DTW/time: <u>NA</u>
Final (after pump priming) DTW/time: <u>NA</u>	Max. sustainable pump rate (mL/min): <u>NA</u>
Free product (circle): <u>LNAPL / DNAPL</u>	Appearance of product: <u>NA</u>
Volume of water removed during priming (mL): <u>NA</u>	Discharge tube diameter (3/8" or 1/4"): <u>NA</u>
Discharge tube length (ft.): <u>NA</u>	Inlet reducer used (Y/N): <u>NA</u>
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = <u>NA</u> psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: <u>Mike V. Leach / Mark Brown</u>	PID/FID reading (well head/background): <u>0.0</u>
Purge date/beginning time: <u>5/11/05</u>	Purge date/completion time: <u>5/11/05 1345</u>
Initial (pre-purging) DTW (ft. BTOC): <u>19.51</u>	Final (post-purging) DTW (ft. BTOC): <u>19.51 (24)</u>
Calculated tubing + pump volume: <u>NA</u>	No. of tubing + pump volumes purged: <u>33.13 Liters</u>
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = <u>NA</u> psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1138	20.18	480	1840	19.97	3.531	4.36	200.6	1.92	25.5
1145	20.74	490	4830	19.42	2.874	5.15	145	0.68	24.8
1204	22.45	480	18950	19.57	2.532	5.25	155.5	1.39	18.9
1216	23.45	480	19710	19.48	2.327	5.62	142.8	1.87	21.5
1235	24.94	480	28820	19.61	2.219	5.75	138.2	1.67	14.9
1245	25.59	480	32270	19.60	2.243	5.73	139.9	1.67	10.08
1313	27.1	480	33.630	19.94	1.934	5.71	145.6	1.70	6.8
1345	Purged	24							



Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

Sample Collection Log

00043665

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW63

Sample Number: LHSMW63-MAY

Sample Name: LHSMW63-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: PERISTALTIC Pump

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5/12/05 | 5/13/05 | 5/15/05

Collection Time: 1025 | 0915 | 1230

Start Depth: 21.78 | 21.79 | 21.79

End Depth: dry | dry | dry

Sample Matrix: WATER

Sample Team: JMV, M.Bin, + S. Mallo

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type	
VOC-FULL	N	A	3	40	mL	VOA VIAL	5/12/05
METALS-W	N	B	1	1000 mL	HDPE		5/13/05 + 5/15/05
METALS-DIS	N	C	1	1000 mL	HDPE		5/12/05 + 5/15/05
Dioxins-Furans	N	D	2	1	L	Amb. Glass	NO SAMPLE
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass	NO SAMPLE
PERC	N	F	1	1	L	HDPE	NO SAMPLE

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Groundwater Information:

Measured Well Depth: 22.12

Depth To Water: 20.90

Comments: INSUFFICIENT WATER RECHARGE TO COLLECT + MEASURE
WATER QUALITY PARAMETERS, DIOXINS FURANS, DIOXIN-FURDIS, AND
PERCHLORATE

Sketch Location:

Logged BY / Date: JMV. 5/16/05

Reviewed BY / Date: _____

Sample Collection Log

00043666

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW63

Sample Number: LHSMW63-MAY

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal) L
Line 1101 5/16/05	1101	20.92	243.5	6.25	0.594	18.0	7.16	20.66	0.4
Sample:	INSUFFICIENT WATER Recharge To Measure								

Logged BY / Date: PAV 5/16/05

Reviewed BY / Date: _____

Sheet of _____

[illegible][illegible]

Sample Information	
Sample ID: <u>LHSMW63-MAY05</u>	Sample collection date/time: <u>5</u>
Duplicate sample collected (Y/N): <u>N</u>	Duplicate sample ID: <u>N/A</u>
Split sample collected (Y/N): <u>N</u>	Split sample ID: <u>N/A</u>
COC No(s): _____	

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VK	P260 B	2 @ 40 ml			
METALS - W	60 ml / 100 ml 74-79	1 @ 500 ml			
METALS - DIS	" "	1 @ 500 ml			

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043669

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW64

Sample Number: LHSMW64-MAY

Sample Name: LHSMW64-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: PERISTALTIC Pump

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5-12-05

Collection Time: 0915

Start Depth: 19.85

End Depth: 23.28

Sample Matrix: WATER

Sample Team: J.M. VALESKY / M. BROWN

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Analytical Suite	Containers					
	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	500 mL	HDPE
METALS-DIS	N	C	1	1000	500 mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass
PERC	N	F	1	1250	ML	HDPE

Groundwater Information:

Measured Well Depth: 27.8

Depth To Water: 19.85

Comments: _____

Sketch Location: _____

Logged BY / Date: _____

Reviewed BY / Date: _____



Shaw E & I, Inc.

Sample Collection Log

00043670

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW64

Sample Number: LHSMW64-MAY

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal) 402
0912 JMV	0912	19.85	236	6.22	0.270	23.5	4.22	19.4	125
Sample: 0915	23.28	22.71	6.24	0.272	8.6	5.43	21.5	21.2	512.5

Logged BY / Date: _____

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

Sheet 1 of

Operable Unit/Site ID: <u>48</u>	Sampling location ID: <u>LHSMW64</u>
Project Name/ID: <u>LHAAP</u>	Sample ID: <u>LHSMW64-MAY05</u>
Weather: <u>Clear/Sunny H=78°F to 90°F</u>	Collection Time/Date: <u>5/12/05 0915</u>

Pump Installation

Pump installation crew: _____	Installation date/beginning time: _____
PID/FID reading (well head/background): _____	Installation date/completion time: _____
Casing diameter (inches): _____	Screen interval (ft. BTOC): _____ to _____
Total well Depth (ft. BTOC): _____	Pump intake depth (ft. BTOC): _____
Initial (pre-installation) DTW/time: _____	Post-installation DTW/time: _____
Final (after pump priming) DTW/time: _____	Max. sustainable pump rate (mL/min): _____
Free product (circle): <u>LNAPL / DNAPL</u>	Appearance of product: _____
Volume of water removed during priming (mL): _____	Discharge tube diameter (3/8" or 1/4"): _____
Discharge tube length (ft.): _____	Inlet reducer used (Y/N): _____
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = _____ psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: <u>Mike Valdez / Mark Brown</u>	PID/FID reading (well head/background): <u>0.0</u>
Purge date/beginning time: <u>0910 5-11-05</u>	Purge date/completion time: <u>5/11/05 10:30</u>
Initial (pre-purging) DTW (ft. BTOC): <u>19.8</u>	Final (post-purging) DTW (ft. BTOC): <u>DRY</u>
Calculated tubing + pump volume: <u>NA</u>	No. of tubing + pump volumes purged: _____
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = <u>NA</u> psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
* 0910	20.69	250	500	19.16	0.257	5.99	186.4	2.1	560.0
1000	23.81	480	15L	18.5	0.257	6.0	179.5	1.84	11.0
1011	24.65	480		18.5	0.259	6.04	139.7	1.69	7.1
1020	25.76	495		18.5	0.261	6.06	139.2	1.86	8.6
1030	27.31	480		18.6	0.262	6.06	126.1	2.1	35.1

* INDICATES STOP PURGING TO FIX TUBING IN PERISTALTIC PUMP @ 0938

Sample Collection Log

00043673

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: **LHSMW65**

Sample Number: **LHSMW65-MAY**

Sample Name: **LHSMW65-MAY05-GW-REG**

Sampling Method: **SP**

Sample Type: **GW**

Sample Purpose: **REG**

Sampling Equip: _____

QC Partners:

(TB)

(ER)

(FB)

Task: **GW-MAY05**

Collection Date: See Comment

Collection Time: See Comment

Start Depth: 20.37

End Depth: 20.37

Sample Matrix: **WATER**

Sample Team: PNV M. Brown

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass
PERC	N	F	1	1	L	HDPE

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Groundwater Information:

Measured Well Depth: 20.5

Depth To Water: 20.37

Comments: UNABLE TO PURGE VIA PERISTALTIC PUMP, ONLY 0.13 OF H₂O IN WELL (HEAD), THUS NO SAMPLE COLLECTED

Sketch Location:

Logged BY / Date: PNV 5/10/05

Reviewed BY / Date: _____

Sample Collection Log

00043674

Page 2 of 2

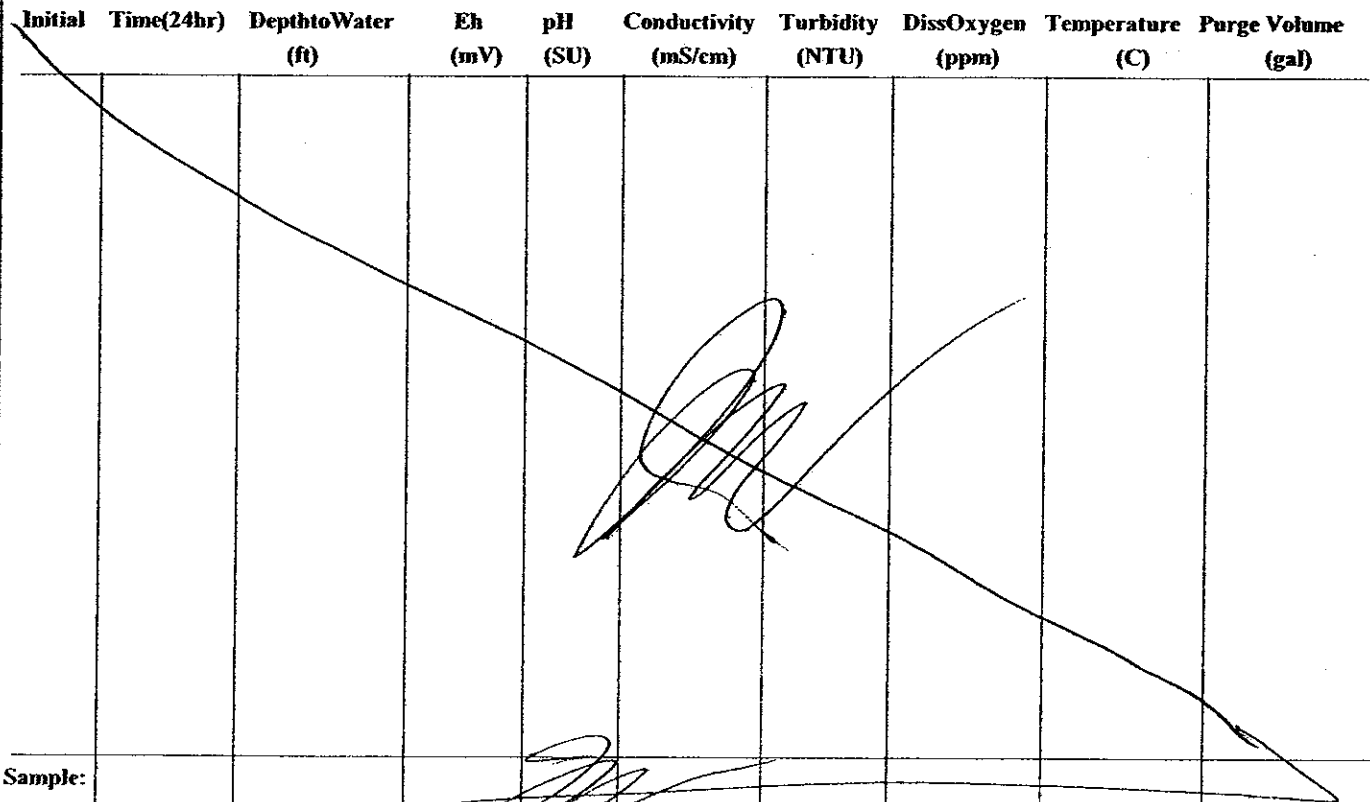
845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW65


Sample Number: LHSMW65-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
									
Sample:									

Logged BY / Date: SAT/ALSK 5/10/05

Reviewed BY / Date: _____

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1520	20.37	-	COULD NOT PURGE H ₂ O FROM BARL						
									

Sample Collection Log

00043677

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: **LHSMW66**

Sample Number: **LHSMW66-MAY**

Sample Name: **LHSMW66-MAY05-GW-REG**

Sampling Method: **SP**

Sample Type: **GW**

Sample Purpose: **REG**

Sampling Equip: PERISTALTIC Pump

QC Partners: _____

(TB) _____

(ER) _____

(FB) _____

Task: **GW-MAY05**

Collection Date: 5-11-05 / 5-12-05
15:10 hrs

Collection Time: 15:10 hrs / 1738

Start Depth: 19.97 / 19.97

End Depth: Dry / Dry

Sample Matrix: **WATER**

Sample Team: J. Valeski, M. Brown

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Analytical Suite	Containers						Type
	Flt	Frtn	Qty	Size	Units		
VOC-FULL	N	A	3	40	mL	VOA	VIAL
METALS-W	N	B	1	1000	500 mL	HDPE	
METALS-DIS	N	C	1	1000	500 mL	HDPE	
Dioxins-Furans	N	D	2	1	L	Amb. Glass	NO SAMPLE
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass	NO SAMPLE
PERC	N	F	1	1	L	HDPE	

Groundwater Information:

Measured Well Depth: _____

Depth To Water: _____

Comments: INSUFFICIENT WATER RECHARGE TO COLLECT &
MEASURE WATER QUALITY PARAMETERS, DIOXIN-FURANS, DIOXIN-
FUR-DIS

Sketch Location: _____

Logged BY / Date: JMV 5/15/05

Reviewed BY / Date: _____

Sample Collection Log

00043678

Page 2 of 2

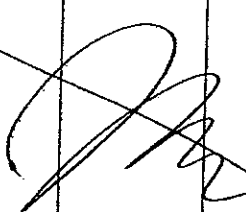
845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW66

Sample Number: LHSMW66-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal) L
5/10/05	7555	19.7		6.9	1.104	1.8	4.31	22.3	0.50
									
Sample:	INSUFFICIENT WATER RECHARGE DURING SAMPLING TO COLLECT/MASURE								

Logged BY / Date: gfw 5/15/05

Reviewed BY / Date: _____

* INDICATES INITIAL DEPTH TO WATER PRIOR TO PURGING

Appendix B

***Groundwater Sampling Forms
LHAAP-35C(53)***



Sample Collection Log

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: 35C-091504-MK

Location Code: FIELDQC
 Sample Number: 091404-ER
 Sample Name: FIELDQC-BW-091404-ER-ER
 Sampling Method: GRAB
 Sample Type: BW

Sample Purpose: ER

Task:
 Collection Date: 14-SEP-04
 Collection Time: 17:30
 Start Depth:
 End Depth:
 Sample Matrix: WQ
 Sample Team: KE

Analytical Suite	Containers				
	Flt	Frtn	Qty	Size	Units Type
VOC-FUEL	N	A	3	40	ml VOC VIAL
PERC	N	B	1	250	ml HDPE

ERPIMS Values:
 Saccide:
 Lot Control#:

Comments:

DI RINSATE THROUGH BLADDER PUMP AND TUBING

Associate w/ 106

Sketch Location:

Logged BY / Date: *[Signature]* 9/15/04

Reviewed BY / Date: *[Signature]* 9/15/04

Page 1 of 2

Manager: Praveen Srivastav

Location Code: 106

Sample Number: L0001-106

Sample Name: L0001-106-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip:

OC Partners:

(TB) 091504-TB

(ER) 091404-ER

(FB) *W/A*

Containers

[illegible]

WIC TITLE	N A 3 10	41	10A241
ERIC	N B 1 1	1	1E11BPP

Task: GW DATA GAPS AUG04

Collection Date: 9/14/04

Collection Time: 1530

Start Depth: 12.82

End Depth: 13.34

Sample Matrix: WATER

Sample Team: K. Everett, J. Rodriguez

ERPIMS-Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 23.90

Depth To Water: 12.82

Comments:

Additional sample sent for MS/MSD but not logged or associated w/ coc per Diane Meyer (Project chemist; Shaw Etc)

Sketch Location:

Logged BY/ Date: K Everett 9/14/02

Reviewed BY / Date: 2/15/04



Sample Collection Log

Page 2 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 106

Sample Number: L0001-106QC

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
See on Sampling Form Klauder									
Sample:	1545	13.34	299.7	4.88	0.481	16.5	2.90	23.78	

Logged BY / Date: K Everett 9/14/94

Reviewed BY / Date: D. H. H. 9/14/94



Sample Collection Log

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: 35C-091504-MK

Location Code: FIELDQC
 Sample Number: 091504-ER
 Sample Name: FIELDQC-BW-091504-ER-ER
 Sampling Method: GRAB
 Sample Type: BW
 Sample Purpose: ER

Task:
 Collection Date: 15-SEP-04
 Collection Time: 13:15
 Start Depth:
 End Depth:
 Sample Matrix: WQ
 Sample Team: WC

Analytical Suite		Containers			
Fit	Prtn	Qty	Size	Units	Type
VOC	EDL	N	A	3	40 mL VOA VIAL
PERC		N	B	1	250 mL HDPE

ERPIMS Values:

Sacode:

Lot Control#:

Comments:

DI RINSATE THROUGH BLADDER PUMP AND TUBING
 ASSOC w/ LHS MW 69

Sketch Location:

Logged BY / Date: De. H. H. / 9/15/04

Reviewed BY / Date: De. H. H. / 9/15/04

Page 1 of 2

Manager: Praveen Srivastav

RFA / COC Number: 35C-091504-n mk

Task: GW DATA GAPS AUG04

Collection Date: 9/14/04

Collection Time: 1530

Sample Purpose: FD

Start Depth: 12.92

Sampling Equip:

End Depth: 13.34

QC Partners:

Blackbox pump

Sample Matrix: WATER

(TB) 091504-TB

(ER) 091404-BA

(FB) *WJH*

Sample Team: K. Everett, L. Rodriguez

Containers

Analytical Suite

Flt	Frtn	Qty	Size	Units	Type
-----	------	-----	------	-------	------

ERPIMS Values:

Soccode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 23.90

Depth To Water: 12.82

Comments:

Sketch Location:

Logged BY / Date: KEverett 9/14/01

Reviewed BY/ Date: 2/15/21 9/15/21



Sample Collection Log

Page 2 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 106

Sample Number: L0001-106

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
<i>See GLW Sampling</i>									
Sample:	1545	13.34	299.7	4.88	0.481	15.5	2.90	23.78	

Logged BY / Date: KEvenett 9/14/04Reviewed BY / Date: De 10/11/04 9/15/04



GROUNDWATER SAMPLING FORM

Sheet 1 of

Operable Unit/Site ID: _____

Project Name/ID: LHAAPWeather: hot, sunny Mosquitos aboundSampling location ID: Site 35C (53) #106Sample ID: L0001-106

Collection Time/Date: _____

Pump Installation

Pump installation crew: K. Everett, J. RodriguezPID/FID reading (well head/background): 0 / 0 ppmCasing diameter (inches): 2" PVCTotal well Depth (ft. BTOC): 23.90 (TOC PVC CSG)Initial (pre-installation) DTW/time: 12.82Final (after pump priming) DTW/time: 14.20Free product (circle): LNAPL / DNAPL

Volume of water removed during priming (mL): _____

Discharge tube length (ft.): 30'

Pneumatic Controller Tuning:

Initial air pressure = $H \text{ (ft.)} \times 0.43 =$ _____ psiInstallation date/beginning time: 9/14/04 1300Installation date/completion time: 9/14/04 1330Screen Interval (ft. BTOC): 13.5 to 23.5Pump intake depth (ft. BTOC): 19'

Post-installation DTW/time: _____

Max. sustainable pump rate (mL/min): _____

Appearance of product: NADischarge tube diameter (3/8" or 1/4"): 3/8Inlet reducer used (Y/N): N

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	15	15	12	20	20	20			
Refill Setting	10	11	11	11	11	11			
Discharge Setting	5	9	9	9	9	9			
Flow rate (mL/min)	380	280	280	330	190	120			

Purging

Purging/sampling crew: A/A

Purge date/beginning time: _____

Initial (pre-purging) DTW (ft. BTOC): _____

Calculated tubing + pump volume: NA

Pneumatic Controller Tuning:

Initial air pressure = $H \text{ (ft.)} \times 0.43 =$ _____ psi

PID/FID reading (well head/background): _____

Purge date/completion time: _____

Final (post-purging) DTW (ft. BTOC): _____

No. of tubing + pump volumes purged: _____

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1340	14.20	280	0.9	21.34	0.518	4.87	246.3	4.63	357.2
1345	14.20	280	1.8	21.40	0.518	4.87	256.2	4.60	352.0
1350	14.15	280	2.7	21.68	0.508	4.84	269.6	4.64	246.7
1355	14.29	330	4.35	21.45	0.507	4.83	274.5	4.67	192.8
1400	14.29	190	5.3	21.65	0.506	4.83	276.3	4.83	168.2
1405	14.00	160	6.1	21.99	0.502	4.84	281.4	5.07	150.3
1410	13.49	160	6.9	22.09	0.502	4.84	282.3	5.07	132.8
1415	13.32	100	7.4	22.47	0.439	4.85	287.5	4.85	116.7

(Shape
File
8'-23.5
Screen)



GROUNDWATER SAMPLING FORM

Sheet of

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C) ±10%	Electrical Conductivity (uMhos/cm) ±3%	pH ±0.1	Eh (mv) ±10	DO (mg/L) ±10%	Turbidity (NTU) ±10%
1420	13.29	100	7.9	22.94	0.439	4.85	289.4	4.3	95.7
1425	13.49	120	8.5	23.09	0.439	4.85	292.6	3.92	59.1
1430	13.49	120	9.1	22.89	0.438	4.85	293.3	3.75	48.9
1435	13.34	120	9.7	23.20	0.436	4.86	298.2	3.70	46.5
1440	13.34	120	10.3	23.49	0.496	4.91	299.2	3.54	39.4
1445	13.34	120	10.9	23.52	0.496	4.87	299.6	3.53	37.3
1450	13.34	110	11.45	23.43	0.495	4.86	299.2	3.31	32.0
1455	13.34	110	12	23.29	0.494	4.86	299.6	3.26	25.1
1500	13.34	110	12.55	23.93	0.490	4.86	299.6	3.16	22.3
1505	13.34	110	13.1	23.06	0.488	4.87	300.2	3.06	20.2
1510	13.34	110	13.65	23.09	0.487	4.87	300.0	3.02	20.5
1515	13.34	110	14.2	23.57	0.486	4.87	299.5	2.96	17.3
1520	13.34	110	14.75	22.98	0.483	4.87	300.0	2.98	15.3
1525	13.34	110	15.3	23.04	0.482	4.87	301.7	2.85	13.9

10-20
20

Sampling

Sampling beginning time: 1530Sampling completion time: 1645

Water Quality Parameter Measurements									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1545	13.34	110	16.85	23.78	0.481	4.88	299.7	2.90	15.5

Sample Information

Sample ID: L0001-106Sample collection date/time: 9/14/04 1545Duplicate sample collected (Y/N): YDuplicate sample ID: L0001-106 GCSplit sample collected (Y/N): NSplit sample ID: NACOC No(s):

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
DOC		3 vials (9)			
Residual		1 Plastic (3)			

Comments:

Very soft bottom; dedicated bailer in well.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - liter



Sample Collection Log

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: 35C-091504-MK

Location Code: 107

Sample Number: L0001-107

Sample Name: L0001-107-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip: QED Bladder Pump

QC Partners:

(TB) 091504-TB

(ER) N/A

(FB) N/A

Task: GW DATA GAPS AUG04

Collection Date: 9/16/04

Collection Time: 1210

Start Depth: 11.98

End Depth: 12.10

Sample Matrix: WATER

Sample Team: K. Everett, J. Rodriguez

ERPIMS Values:

Sacode:

Lot Control#:

Analytical Suite	Containers	Flt Frtn Qty	Size	Units	Type
YOK 1001	1	1	100	ml	NON VIAL
PERC	1	1	100	ml	HDPE

Groundwater Information:

Measured Well Depth: 22.46

Depth To Water: 10.22 (initial)

Comments:

Sketch Location:

Logged BY / Date: K. Everett 9/15/04

Reviewed BY / Date:



Sample Collection Log

Page 2 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 107

Sample Number: L0001-107

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
<i>See GW Sampling Form</i>									
Sample:	1215	12-10	49.7	5.49	0.943	18.5	0.72	24.98	5 gal

Logged BY / Date: K Everett 9/15/04

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

Sheet 1 of 3

Operable Unit/Site ID: _____ Sampling location ID: SIL 35C(53) 107
 Project Name/ID: LHAAP Sample ID: _____
 Weather: hot sunny Collection Time/Date: _____

Pump Installation

Pump installation crew: K Everett J Rodriguez Installation date/beginning time: 9/15/04 0920
 PID/FID reading (well head/background): 30 / 4.5-5.7 Installation date/completion time: 9/15/04 0945
 Casing diameter (inches): 2" PVC Screen Interval (ft. BTOC): 12 (est.) to 22
 Total well Depth (ft. BTOC): 22.46 (TOC) Pump intake depth (ft. BTOC): 17'
 Initial (pre-installation) DTW/time: 10.22 9:38 Post-installation DTW/time: _____
 Final (after pump priming) DTW/time: 11.98 10:05 Max. sustainable pump rate (mL/min): _____
 Free product (circle): LNAPL / DNAPL Appearance of product: NA
 Volume of water removed during priming (mL): _____ Discharge tube diameter (3/8" or 1/4"): 3/8
 Discharge tube length (ft.): 30' Inlet reducer used (Y/N): N

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	20	17	10	10	10				
Refill Setting	10	11	12	12	12				
Discharge Setting	5	9	8	8	9				
Flow rate (mL/min)	—	280	45	100	120				

Purging

Purging/sampling crew: A/A PID/FID reading (well head/background): _____
 Purge date/beginning time: _____ Purge date/completion time: _____
 Initial (pre-purging) DTW (ft. BTOC): _____ Final (post-purging) DTW (ft. BTOC): _____
 Calculated tubing + pump volume: NA No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
10:00	12.70	280	1.4	22.65	1.140	5.64	16.4	1.50	71.8
10:05	11.98	100	1.9	23.10	1.141	5.63	19.9	1.41	123.7
10:10	11.98	100	2.4	23.40	1.140	5.62	21.6	1.36	103.2
10:15	11.90	100	2.9	23.58	1.138	5.61	23.9	1.35	98.3
10:20	11.87	100	3.4	23.79	1.133	5.60	25.7	1.15	84.7
10:25	11.87	100	3.9	23.83	1.126	5.60	26.5	1.04	85.7
10:30	11.60	100	4.4	23.93	1.114	5.58	26.1	1.03	89.7
10:35	11.60	100	4.9	23.94	1.101	5.58	24.6	1.00	92.4

280
0

1400

Shape
File
initials
4-19-04
Semi



GROUNDWATER SAMPLING FORM

Sheet 2 of 3

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C) +/- 10%	Electrical Conductivity (uMhos/cm) + 3%	pH ±0.1	Eh (mv) ±10	DO (mg/L) ±10%	Turbidity (NTU) ±10%
1040	11.55	100	5.40	23.90	1.077	5.58	22.8	0.97	94.7
1045	11.55	100	6.9	23.98	1.064	5.58	21.8	0.96	94.8
1050	11.55	100	7.4	24.12	1.052	5.58	20.3	0.94	92.9
1055	11.57	100	8.9	24.34	1.042	5.58	21.6	0.93	91.6
1100	11.59	100	9.45	24.36	1.038	5.57	21.1	0.93	85.7
1105	11.62	120	10.05	24.21	1.008	5.56	23.1	0.85	46.7
1110	11.62	120	10.65	24.18	0.994	5.55	26.7	0.87	71.2
1115	11.92	120	11.25	23.98	0.983	5.53	29.7	0.85	60.0
1120	11.92	120	11.85	23.93	0.973	5.52	34.4	0.94	51.4
1125	11.92	120	12.45	23.76	0.969	5.52	36.9	0.81	48.7
1130	12.10	120	13.05	23.77	0.969	5.52	37.5	0.78	43.0
1135	12.10	120	13.65	23.68	0.968	5.51	37.9	0.73	40.9
1140	12.10	120	14.25	23.71	0.966	5.51	39.1	0.78	39.2
1145	12.10	120	14.85	23.71	0.964	5.51	39.4	0.75	34.2

Sampling

Sampling beginning time: _____

Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: L0001-107

Sample collection date/time: _____

Duplicate sample collected (Y/N): N

Duplicate sample ID: _____

Split sample collected (Y/N): N

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VOC		3-Vials			
Pestic.		1-Plastic, upg			

Comments: Soft obstruction @ 7'

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter.

110 120
5 5
30 60

Sheet 3 of 3.

Site 35C (S3)
Well 107

Sampling
Sampling beginning time: 1210 Sampling completion time: ~~1250~~ 1245

Sampling

Sampling beginning time: 1210

Sampling completion time: ~~1250~~ 1245

Sample Information	
Sample ID: _____	Sample collection date/time: _____
Duplicate sample collected (Y/N): _____	Duplicate sample ID: _____
Split sample collected (Y/N): _____	Split sample ID: _____
COC No(s): _____	

Sample Information

Sample ID: _____
Duplicate sample collected (Y/N): _____
Split sample collected (Y/N): _____
COC No(s): _____

Sample collection date/time: _____
Duplicate sample ID: _____
Split sample ID: _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: soft obstruction @ 7' ~ moved water level around until slipped through

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

sk-35C

RFA / COC Number: 35C-091504-60
35C-091504-mk

Location Code: LHSMW67

Sample Number: L0001-LHSMW67

Sample Name: L0001-LHSMW67-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip: Bladder Pump

QC Partners:

(TB)

091504-TB

(ER)

N/A

(FB)

N/A

Task: GW DATA GAPS AUG04

Collection Date: 9/15/04

Collection Time: 12:30

Start Depth: 18.07

End Depth: 19.07

Sample Matrix: WATER

Sample Team: A. Willmore, B. Ansley

ERPIMS Values:

Sacode:

Lot Control#:

Analytical Suite

Containers

Fit Frtn Qty Size Units Type

VOC PUEE	N	A	3	40	ml	VDA VIAL
PERC	N	B	1	1	L	HDPE
Dioxin Furans	N	C	1	1	L	Amb Glass

Groundwater Information:

Measured Well Depth: 22.69

Depth To Water: 17.11

Comments: 1.96 FEET OF WATER Purged before Stabilization

Sketch Location:

Logged BY / Date:

M. All

9/15/04

Reviewed BY / Date:

P. Willmore 9/15/04



Sample Collection Log

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW67

Sample Number: L0001-LHSMW67

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal) L
Sample:	1315	19.00	96.6	5.93	0.893	58.3	1.90	31.10	17.30

Logged BY / Date:

M. M. C.
9/16/04

Reviewed BY / Date:

P. Srivastav 9/15/04



GROUNDWATER SAMPLING FORM

Sheet 1 of 2

Operable Unit/Site ID: <u>386</u>	Sampling location ID: <u>LHSM-7</u>
Project Name/ID: <u>LHAAP</u>	Sample ID: <u>LHSM-67</u>
Weather: <u>Partly Cloudy 90°</u>	Collection Time/Date: <u>9/15/04 12:30</u>

Pump Installation

Pump installation crew: <u>A. Williams B. Anley</u>	Installation date/beginning time: <u>9/15/04 9:40</u>
PID/FID reading (well head/background): <u>0.0</u>	Installation date/completion time: <u>9/15/04 9:41</u>
Casing diameter (inches): <u>4"</u>	Screen Interval (ft. BTOC): <u>12.69 to 21.69</u>
Total well Depth (ft. BTOC): <u>21.69</u>	Pump intake depth (ft. BTOC): <u>19.9' 9:49</u>
Initial (pre-installation) DTW/time: <u>17.11</u>	Post-installation DTW/time: <u>17.05</u>
Final (after pump priming) DTW/time: _____	Max. sustainable pump rate (mL/min): _____
Free product (circle): <u>LNAPL / DNAPL</u>	Appearance of product: _____
Volume of water removed during priming (mL): _____	Discharge tube diameter (3/8" or 1/4"): <u>3/8"</u>
Discharge tube length (ft.): _____	Inlet reducer used (Y/N): <u>No</u>
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = <u>8.667</u> psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: <u>A. Williams B. Anley</u>	PID/FID reading (well head/background): <u>0.0</u>
Purge date/beginning time: <u>9/15/04 10:05</u>	Purge date/completion time: <u>9/15/04</u>
Initial (pre-purging) DTW (ft. BTOC): <u>17.11</u>	Final (post-purging) DTW (ft. BTOC): _____
Calculated tubing + pump volume: <u>NA</u>	No. of tubing + pump volumes purged: _____
Pneumatic Controller Tuning:	
Initial air pressure = H (ft.) X 0.43 = <u>8.667</u> psi	

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	11	16	14						
Refill Setting	10	10	11.4						
Discharge Setting	5	5	3.4						
Flow rate (mL/min)	55	120	100						

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (ft ³)	Temp. (degrees C)	Electrical Conductivity (uMhos/cm)	pH	EH (mv)	DO (mg/L)	Turbidity (NTU)
10:40	12.11	55	0.110	20.44	0.842	5.95	24.56	2.33	3371.7
10:45		55	0.165	29.74	0.857	5.95	16.5	1.71	3351.4
10:50		55	0.160	29.32	0.848	5.94	10.8	1.97	3346.1
10:55		120	0.260	29.61	0.861	5.95	16.6	2.05	3357.2
11:00	17.83	120	0.460	26.93	0.870	5.95	28.0	1.73	3337.3
11:05	18.01	100	0.560	27.44	0.880	5.94	27.3	1.49	3330.8
11:10	18.19	100	0.660	28.14	0.882	5.94	27.2	1.46	1376.8
11:15	18.25	100	0.760	28.09	0.885	5.95	28.9	1.49	909.8



GROUNDWATER SAMPLING FORM

Sheet 2 of 2

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
11:20	18.39	100	3.860	28.07	0.993	5.95	79.8	1.66	791.7
11:25	18.98	100	4.360	28.67	0.994	5.95	70.4	1.53	659.0
11:30	18.67	100	4.860	29.18	0.994	5.95	70.9	1.59	515.7
11:35	18.76	100	5.360	29.52	0.996	5.95	70.2	1.55	951.8
11:40	18.87	100	5.860	29.30	0.997	5.94	63.6	1.59	700.1
11:45	18.94	100	6.360	29.55	0.996	5.94	62.8	1.68	683.2
11:50	18.97	100	6.860	30.01	0.995	5.94	61.8	1.71	681.4
11:55	19.00	100	7.360	30.03	0.996	5.94	60.8	1.71	678.9
12:00	19.03	100	7.860	30.11	0.997	5.94	61.0	1.73	375.9
12:05	19.04	100	8.360	30.14	0.997	5.94	60.9	1.74	376.2
12:10	19.06	100	8.860	31.13	0.997	5.94	60.9	1.75	580.4
12:15	19.07	100	9.360	31.13	0.997	5.94	61.5	1.78	381.3

Sampling

Sampling beginning time: 12:30Sampling completion time: 13:00

Water Quality Parameter Measurements									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
13:15	19.00	100	11.36	31.10	0.993	5.93	96.6	1.90	58.3

Sample Information

Sample ID: 446m67Sample collection date/time: 9/15/04 12:50Duplicate sample collected (Y/N): No

Duplicate sample ID: _____

Split sample collected (Y/N): No

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
Perchlorate	314	1x HPLC			
VOCs	8260	2x Vials			
Dioxins/furans		2x FL Amber			

Comments: Water became clear after flow-through cell was emptied and re-filled.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

Page 1 of 2

845714 LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: 35C-091504-MR

Location Code: LHSMW68

Sample Number: L0001-LHSMW6

Sample Name: L0001-LHSMW68-00

Sampling Method: BA

Sample Type: GW

Sample Purpose: REG

Sampling Equip: 1" Disposable PVC bailer

QC Partners:

(TB)

091504-TB

(ER)

(FB)

Task: GW DATA GAPS AUG04

Collection Date: 9/14/04

Collection Time: 16:30

Start Depth: 20.71

End Depth: Bailed Dry

Sample Matrix: WATER

Sample Team: A. Williams, B. Ansley

Containers

Analytical Suite FH Frtn Qty Size Units Type

VOC SULF	N	3	45	ml	VOC VIAL
PH	N	1	1	1	HDPE

ERPIMS Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 24.68

Depth To Water: 20.71

Comments:

Bailed Dry due to low recharge characteristics of site.

Sketch Location:

Logged BY / Date:

9/14/04

Reviewed BY / Date:

9/15/04



Sample Collection Log

Page 2 of 2

845714 LONGHORN AAP
Manager: Praveen Srivastav

Location Code: LHSMW68

Sample Number: L0001-LHSMW6

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
Sample:	NA	NA	NA	NA	NA	NA	NA	NA	NA

Logged BY / Date:

[Signature]
9/14/04

Reviewed BY / Date:

[Signature] 9/15/04



GROUNDWATER SAMPLING FORM

Sheet 1 of 2

Operable Unit/Site ID: 35C Sampling location ID: LHSM 63
 Project Name/#: LHAAP Sample ID: LHSM 63
 Weather: Partly Cloudy 96s Collection Time/Date: 15:30 9/14/04

Pump Installation

Pump installation crew: A. Williams, B. Ansley Installation date/beginning time: NA
 PID/FID reading (well head/background): 0.0 Installation date/completion time: NA
 Casing diameter (inches): 4" Screen Interval (ft. BTOC): 14.68 to 24.68
 Total well Depth (ft. BTOC): 24.68 Pump Intake depth (ft. BTOC): NA
 Initial (pre-installation) DTW/time: 20.71 12:41 Post-installation DTW/time: NA
 Final (after pump priming) DTW/time: NA Max. sustainable pump rate (mL/min): NA
 Free product (circle): LNAPL / DNAPL Appearance of product: NA
 Volume of water removed during priming (mL): NA Discharge tube diameter (3/8" or 1/4"): NA
 Discharge tube length (ft.): NA Inlet reducer used (Y/N): NA

Pneumatic Controller Tuning:

Initial air pressure = $H \text{ (ft.)} \times 0.43 =$ NA psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: A. Williams, B. Ansley PID/FID reading (well head/background): 0.0
 Purge date/beginning time: 9/14/04 NA Purge date/completion time: NA
 Initial (pre-purging) DTW (ft. BTOC): 20.71 Final (post-purging) DTW (ft. BTOC): NA
 Calculated tubing + pump volume: NA No. of tubing + pump volumes purged: NA

Pneumatic Controller Tuning:

Initial air pressure = $H \text{ (ft.)} \times 0.43 =$ NA psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Due to low recharge rate of well
 Bailed Well Dry

Sample Collection Log

00043703

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: 106

Sample Number: 35CWW106-MAY

Sample Name: 35CWW106-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: Bladder Pump/REP

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5-12-05

Collection Time: 1613

Start Depth: 18.5

End Depth: 18.4

Sample Matrix: WATER

Sample Team: J Rogers J Rodriguez

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode: _____

Lot Control#: _____

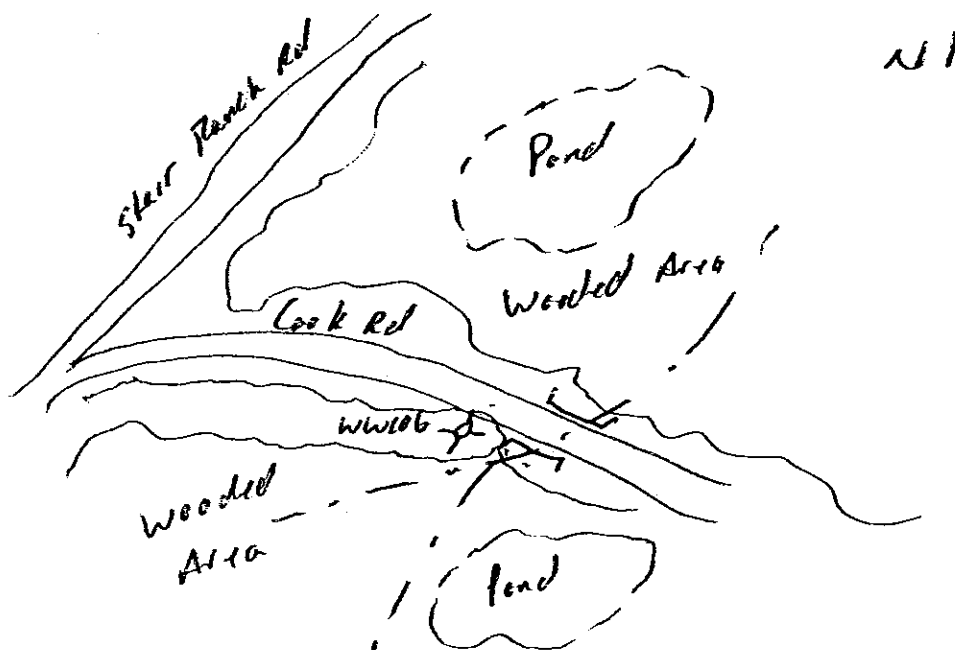
Groundwater Information:

Measured Well Depth: 23.94

Depth To Water: 10.15

Comments: After 3 hours of purging, turbidity values below 25 NTU for at least 45 mins. Given the go ahead to sample.

Sketch Location:



Logged BY / Date: J Rogers 5/12/05

Reviewed BY / Date: _____

Sample Collection Log

00043704
Page 2 of 2

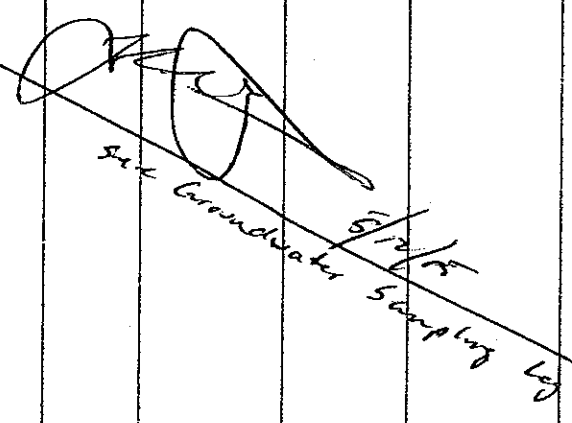
845714 - LONGHORN AAP

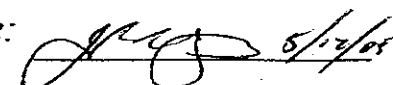
Manager: Praveen Srivastav

Location Code: 106

Sample Number: 35CWW106-MAY

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
 <p>See Groundwater Sampling Log</p>									
Sample:	1648	10.69	348.7	4.46	0.406	15.6	1.21	18.99	Final

Logged BY / Date:  5/12/05

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043705

Sheet 1 of 2

Operable Unit/Site ID: LHAA 35C (53)Project Name/ID: 845719Weather: HOT HUMID Partly CloudySampling location ID: 106Sample ID: 35CWW106 MAY05Collection Time/Date: 5-12-05 1613

Pump Installation

Pump installation crew: J Rogers J RodriguezPID/FID reading (well head/background): 0.0/0.0Casing diameter (inches): 2"Total well Depth (ft. BTOC): 23.98 9.81Initial (pre-installation) DTW/time: 9.16 1115

Final (after pump priming) DTW/time:

Free product (circle): LNAPL / DNAPLVolume of water removed during priming (mL): NADischarge tube length (ft.): 1.5

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Installation date/beginning time: 5-12-05 1300Installation date/completion time: 5-12-05 1305Screen Interval (ft. BTOC): 13 to 23Pump intake depth (ft BTOC): 13Post-installation DTW/time: 10.69 1640Max. sustainable pump rate (mL/min): NAAppearance of product: NADischarge tube diameter (3/8" or 1/4"): 3/8Inlet reducer used (Y/N): N

Purging

Purging/sampling crew: J Rogers J RodriguezPurge date/beginning time: 5-12-05 1306Initial (pre-purging) DTW (ft. BTOC): 10.15Calculated tubing + pump volume: NA

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

PID/FID reading (well head/background): 0.0Purge date/completion time: 5-12-05 1640Final (post-purging) DTW (ft. BTOC): 10.69No. of tubing + pump volumes purged: NA

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	20	20	20	20	20	20	15	15	15
Refill Setting	11.0	11	11	11	11	11	5	5	5
Discharge Setting	9.0	9	9	9	9	9	15	15	15
Flow rate (mL/min)	180	180	180	180	180	180	130	130	130

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1310	10.73	180	.54	21.02	0.427	4.84	297.1	3.14	104.8
1313	10.73	180	1.08	20.19	0.423	4.87	305.7	2.80	122.8
1316	10.73	180	1.62	19.98	0.421	4.89	309.4	2.68	135.0
1319	10.73	180	2.16	19.34	0.415	4.88	314.6	2.36	126.9
1322	10.73	180	2.70	19.36	0.415	4.88	317.2	2.32	116.1
1325	10.73	180	3.24	19.23	0.414	4.85	317.8	2.22	108.6
1355	10.89	130	7.64	20.06	0.418	4.83	322.4	4.42	652
1425	10.69	130	11.04	19.33	0.418	4.71	328.3	2.51	43.2



GROUNDWATER SAMPLING FORM

00043706

Sheet 2 of 2

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1453	10.69	130	14.94	19.24	0.414	4.67	330.2	1.94	31.5
1525	10.69	130	17.84	19.18	0.411	4.54	358.6	1.49	19.7
1550	10.69	130	22.74	19.06	0.409	4.52	346.2	1.09	19.8
1600	10.69	130	24.04	18.76	0.408	4.50	345.7	1.10	17.4
1603	10.69	130	24.43	18.77	0.407	4.49	346.6	0.99	17.1
1606	10.69	130	24.82	18.79	0.406	4.49	346.3	0.99	16.9
1609	10.69	130	25.21	18.79	0.407	4.49	346.4	0.95	16.5
1612	10.69	130	25.60	18.81	0.406	4.49	346.9	0.96	16.3

Sampling

Sampling beginning time: 1613

Sampling completion time: 1640

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1613	10.69	130	25.73	18.79	0.406	4.48	346.9	0.95	16.4
1640	10.69	130	Final	18.99	0.406	4.46	346.7	1.21	15.6

Sample Information

Sample ID: 35CWW106 MW15

Sample collection date/time:

Duplicate sample collected (Y/N): N

Duplicate sample ID: N/A

Split sample collected (Y/N): N

Split sample ID: N/A

COC No(s):

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VOL	Bladder	3x40ml H ₂ O			
Metals - Fe	Bladder	50ml H ₂ O			
Metals - Pb	Bladder	50ml			
Metals - Cu	Bladder	2x1L Amber			
Metals - Ni	Bladder	2x1L Amber			

Comments: 1325 - Back psi down. will make recording every 15 mins - 30 mins depending on turbidity readings will allow flow rate to remain @ 130ml/min. Determine after 3 hours of pumping turbidity readings have been below 25 NTU for at least 1/2 hr, will take 5 consecutive 3 min readings and sample.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

Sample Collection Log

00043707

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: 107

Sample Number: 35CWW107-MAY

Sample Name: 35CWW107-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: _____

QC Partners: _____

(TB) _____

(ER) _____

(FB) _____

Task: GW-MAY05

Collection Date: 5/12/15

Collection Time: 1430

Start Depth: 9.09

End Depth: 9.23

Sample Matrix: WATER

Sample Team: Anis, G. / Allore, J.

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Groundwater Information:

Measured Well Depth: 22.47

Depth To Water: 6.58

Comments: _____

Sketch Location: _____

Logged BY / Date: _____

Reviewed BY / Date: _____

Sample Collection Log

00043708

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: 107

Sample Number: 35CWW107-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
<div style="position: relative; width: 100%; height: 100%;"> <div style="position: absolute; top: 0; left: 0; right: 0; bottom: 0; border-left: 1px solid black; border-right: 1px solid black; border-bottom: 1px solid black;"></div> </div>									
Sample:	1520	9.09	106.2	5.63	930	10.2	0.32	23.8	6.12

Logged BY / Date: _____

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043709

Sheet 1 of

Operable Unit/Site ID: 351	Sampling location ID: J07
Project Name/ID: LNAH1	Sample ID: 351-107-MAY05
Weather: 1/6 85°F	Collection Time/Date: 1430 15-12-5

Pump Installation

Pump installation crew: Ausby / Allain	Installation date/beginning time:
PID/FID reading (well head/background): 0.0/0.0	Installation date/completion time: 8.
Casing diameter (inches): 2"	Screen Interval (ft. BTOC): to
Total well Depth (ft. BTOC): 22.47	Pump intake depth (ft. BTOC): 14.5'
Initial (pre-installation) DTW/time: 6.58 / 1043	Post-installation DTW/time: 6.10 / 1320
Final (after pump priming) DTW/time: 6.18 / 1325	Max. sustainable pump rate (mL/min):
Free product (circle): LNAPL / DNAPL	Appearance of product:
Volume of water removed during priming (mL):	Discharge tube diameter (3/8" or 1/4"): 1/4"
Discharge tube length (ft.):	Inlet reducer used (Y/N):

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	12								
Refill Setting	12								
Discharge Setting	8								
Flow rate (mL/min)									

Purging

Purging/sampling crew:	PID/FID reading (well head/background):
Purge date/beginning time:	Purge date/completion time:
Initial (pre-purging) DTW (ft. BTOC):	Final (post-purging) DTW (ft. BTOC):
Calculated tubing + pump volume: NA	No. of tubing + pump volumes purged:

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	12	12							
Refill Setting	12	11							
Discharge Setting	8	9							
Flow rate (mL/min)	130	100							

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1330	6.50	Flow 611	0.1	24.48	961	5.51	130	1.77	12.5
1333	6.60	230	0.700	23.10	956	5.52	130.2	1.12	20.5
1336	6.87	130	1.100	23.43	948	5.52	129.7	0.90	20.6
1339	6.87	130	1.520	23.78	947	5.54	129.8	0.71	17.9
1342	6.56	100	1.800	24.37	946	5.55	129.8	0.76	17.1
1345	6.30	66	2.00	24.75	948	5.55	133.1	0.78	16.8
1348	6.18	66	2.2	25.26	946	5.55	134.2	0.61	15.6
1351	6.28	100	2.5	25.99	950	5.54	135.2	0.54	13.5



GROUNDWATER SAMPLING FORM

00043710

Sheet ___ of ___

Water Quality Parameter Measurements (continued)

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1354	8.24	100	2.8	26.39	949	5.55	136.1	0.55	12.4
1357	8.20	100	3.1	26.56	951	5.55	134.9	0.56	13.1
1400	8.23	100	3.4	26.69	952	5.55	135.0	0.54	11.7
1403	8.25	100	3.7	26.74	952	5.54	133.5	0.51	9.1
1406	8.56	100	4.0	25.84	969	5.53	128.8	0.41	8.9
1409	8.99	100	4.3	24.07	962	5.53	126.0	0.39	13.3
1412	9.04	100	4.6	22.95	952	5.57	121.1	0.38	16.0
1415	9.09	100	4.9	23.11	938	5.62	114.4	0.38	15.9
1418	9.16	100	5.2	23.47	934	5.63	110.6	0.38	13.6
1421	9.11	100	5.5	23.72	931	5.63	109.3	0.39	12.7
1424	9.13	100	5.8	23.75	931	5.63	107.8	0.37	11.0
1427	9.09	100	6.1	23.80	930	5.63	106.2	0.37	10.2

Sampling

Sampling beginning time: 1430

Sampling completion time: 1510

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1520	9.23	100	—	23.19	928	5.72	88	0.38	4.9

Sample Information

Sample ID: _____
 Duplicate sample collected (Y/N): _____
 Split sample collected (Y/N): _____
 COC No(s): _____

Sample collection date/time: _____
 Duplicate sample ID: _____
 Split sample ID: _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

Sample Collection Log

00043711

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW67

Sample Number: LHSMW67-MAY

Sample Name: LHSMW67-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: Bladder Pump / OGP

QC Partners:

(TB)

(ER)

(FB)

Task: GW-MAY05

Collection Date: 5-13-05

Collection Time: 1045

Start Depth: 18 ft

End Depth: 18 ft

Sample Matrix: WATER

Sample Team: J Rogers, M. J. G. G.

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Groundwater Information:

Measured Well Depth: 22.09

Depth To Water: 14.89

Comments: MS, MSD LHS MW 67 May 05

Sketch Location:



NA

Logged BY / Date:

[Signature] 5/17/05

Reviewed BY / Date:

Sample Collection Log

00043712

Page 2 of 2

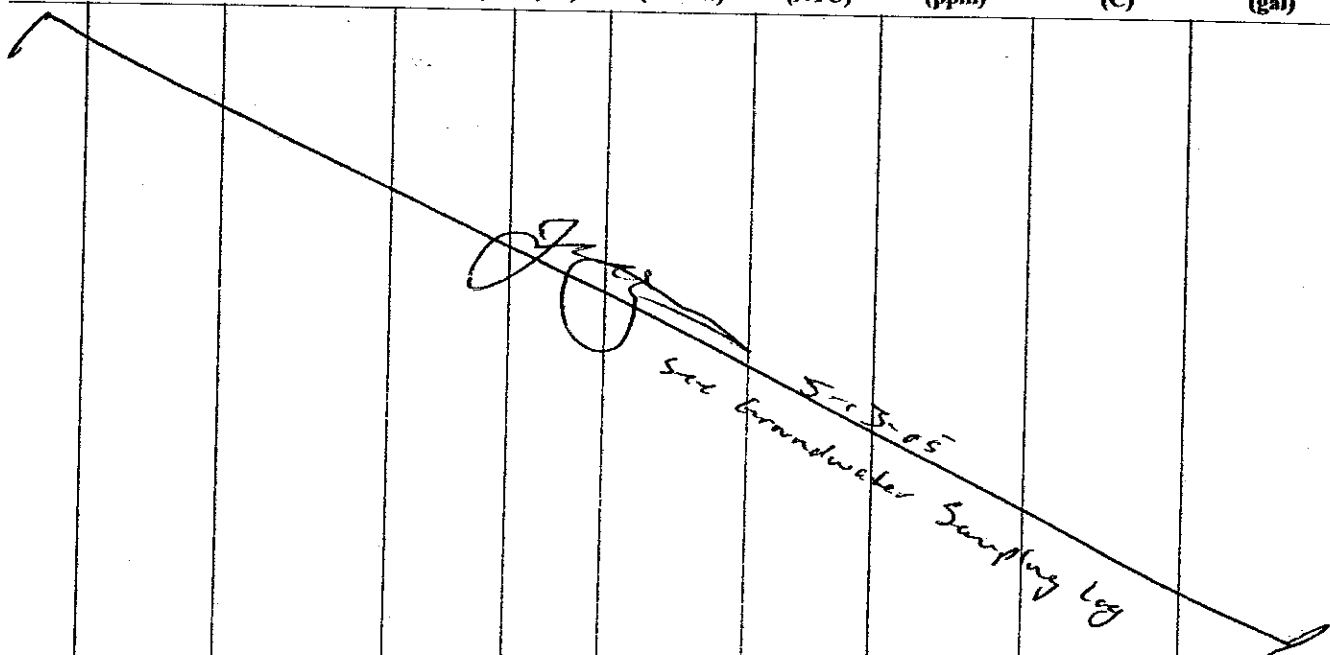
845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW67

Sample Number: LHSMW67-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
 <p>See Groundwater Sampling Log</p>									
Sample:	1226	14.93	260.1	5.88	0.747	31.2	1.21	19.36	Final

Logged BY / Date:

 5/12/15

Reviewed BY / Date:



GROUNDWATER SAMPLING FORM

00043713

Sheet 1 of 2

Operable Unit/Site ID: LH3 35C (53)Sampling location ID: LH3 MW 67Project Name/ID: 845714Sample ID: LH3 MW 67 MAY 05Weather: Cloudy Warm HumidCollection Time/Date: 5-13-05 1045

Pump Installation

Pump installation crew: Ausley/MurrayInstallation date/beginning time: 5-13-05 0825PID/FID reading (well head/background): 0.010/0.010Installation date/completion time: 5-13-05 0930Casing diameter (inches): 4"Screen Interval (ft. BTOC): 12 to 22Total well Depth (ft. BTOC): 22.09Pump intake depth (ft. BTOC): 19Initial (pre-installation) DTW/time: 14.21/(1019)Post-installation DTW/time: 1726 1493Final (after pump priming) DTW/time: NAMax. sustainable pump rate (mL/min): NAFree product (circle): LNAPL/DNAPLAppearance of product: NAVolume of water removed during priming (mL): NADischarge tube diameter (3/8" or 1/4"): 3/8Discharge tube length (ft.): 2Inlet reducer used (Y/N): NO

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: J. Rogers J. RodriguezPID/FID reading (well head/background): 0.2Purge date/beginning time: 5-13-05 0830Purge date/completion time: 5-13-05Initial (pre-purging) DTW (ft. BTOC): 14.25Final (post-purging) DTW (ft. BTOC): 14.93Calculated tubing + pump volume: NANo. of tubing + pump volumes purged: NA

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	15	15	18	15	15	15	15	15	
Refill Setting	11.4	11.4	6.0	6.0	6.0	6	6	6	
Discharge Setting	3.6	3.6	14.0	14.0	14.0	14.0	14	14	
Flow rate (mL/min)	100	60	140	140	140	120	120	120	

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0833	14.69	100	.30	18.84	0.746	6.13	361.6	1.94	28.0
0836	14.74	60	.48	18.67	0.747	6.09	351.4	1.76	29.1
0839	14.72	140	.70	18.41	0.747	5.99	349.6	1.67	30.4
0842	14.92	140	1.32	18.41	0.747	5.98	342.2	1.65	31.0
0845	14.82	140	1.74	18.51	0.747	5.96	338.6	1.62	30.9
0848	14.82	140	2.16	18.59	0.747	5.95	330.9	1.70	31.2
0918	14.82	120	2.72	19.02	0.746	5.93	290.7	1.31	32.2
0942	14.92	120	2.82	19.03	0.745	5.91	290.1	1.30	32.1



GROUNDWATER SAMPLING FORM

00043714

Sheet 2 of 2

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0957	14.94	120	9.32	19.09	0.746	5.91	278.9	1.26	32.1
1012	14.96	100	10.92	19.41	0.749	5.90	273.4	1.24	32.1
1027	14.86	100	12.32	19.78	0.750	5.89	268.5	1.27	31.4
1030	14.86	100	12.62	19.26	0.749	5.89	268.2	1.27	30.9
1038	14.88	100	12.92	19.29	0.748	5.89	268.1	1.25	31.2
1038	14.88	100	13.22	19.31	0.748	5.89	267.6	1.25	31.1
1039	14.89	100	13.52	19.27	0.749	5.89	267.9	1.24	31.3
1042	14.79	100	13.82	19.35	0.748	5.89	267.7	1.24	31.1

Sampling

Sampling beginning time: 1045

Sampling completion time: 1225

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1045	14.89	100	14.12	19.28	0.748	5.89	267.3	1.24	31.5
1226	14.93	100	Final	19.36	0.747	5.88	268.1	1.21	31.2

Sample Information

Sample ID: LH5 MW67 MAY05

Sample collection date/time: 5-17-05 1045

Duplicate sample collected (Y/N): N

Duplicate sample ID: N

Split sample collected (Y/N): N

Split sample ID: at LH5 MW67 May05 MS

COC No(s):

LH5 MW67 May05 MS10

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VOL	Bladder	7 x 40 mL HCL			
Metal Tot	Bladder	100 mL HNO ₃ HNO ₃			
Metal As	Bladder	100 mL HNO ₃			
Protein Furan	Bladder	2 x 12 Amber			
Oxygen Diss	Bladder	2 x 12 Amber			

Comments: 0948: Will take reading every 1/2 hour until turbidity approaches
< 25 NTU. 0942: Begin 15 min readings. Turbidity has not moved.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

Sample Collection Log

00043715

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: **LHSMW68**

Task: **GW-MAY05**

Sample Number: **LHSMW68-MAY**

Collection Date: 5/11/15

Sample Name: **LHSMW68-MAY05-GW-REG**

Collection Time: 1450

Sampling Method: **SP**

Start Depth: 19.31

Sample Type: **GW**

Sample Purpose: **REG**

End Depth: 18.31

Sampling Equip: GFD pump

Sample Matrix: **WATER**

QC Partners:

(TB)

(ER)

(FB)

Sample Team: Ansly / Alvin

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FUEL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Scancode: _____

Lot Control#: _____

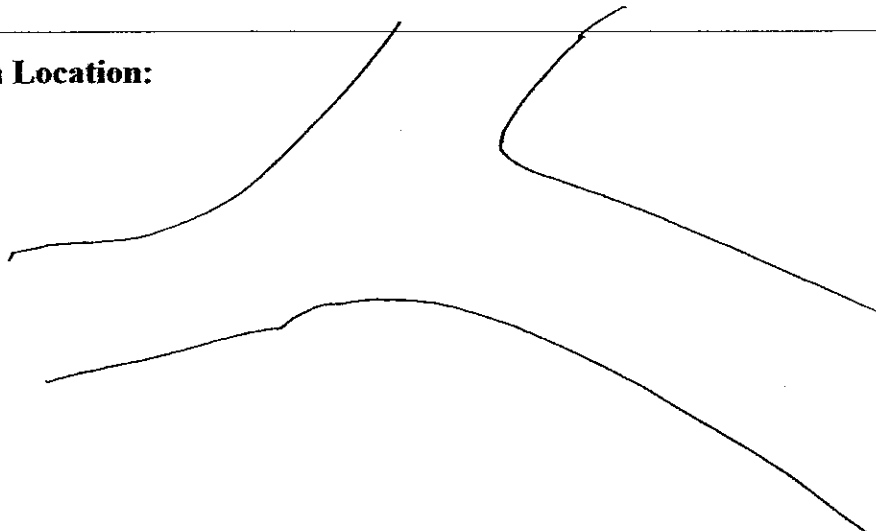
Groundwater Information:

Measured Well Depth: 24.70

Depth To Water: 17.78

Comments: trial direct purge - based on previous slug recharge rates - well recharged
attempted bladder pump - air compressor failed - switched to bottled air.

Sketch Location:



68

Logged BY / Date: _____

Reviewed BY / Date: _____

Sample Collection Log

00043716

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW68

Sample Number: LHSMW68-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
Continued 1424	1424	—	44287	5.14	94	7.6	4.71	20.50	3.9
	1427	18.31	2828	5.14	94	8.1	4.71	20.56	4.2
	1430	18.32	290.1	5.15	94	7.7	4.69	20.52	4.5
	1433	—	291.0	5.14	94	8.0	4.67	20.53	4.8
	1436	18.37	291.9	5.15	94	7.4	4.69	20.48	5.1
	1439	—	291.5	5.15	94	7.0	4.70	20.42	5.4
/									
Sample:	1525	18.31	292.1	5.16	94	5.1	4.75	20.58	6

Logged BY / Date:

AB 5/1/15

Reviewed BY / Date:



GROUNDWATER SAMPLING FORM

00043717

Sheet 1 of 2

Operable Unit/Site ID: LHSM-68 LHAP-35C
Project Name/ID: Long Ln RAP 345714
Weather: clear, sunny ~70°F

Sampling location ID: LHSM-68
Sample ID: LHSM-68
Collection Time/Date: 1:50 5/11/15

Pump Installation

Pump installation crew: Ansley / Allain
PID/FID reading (well head/background): 0.01EL 10.05P
Casing diameter (inches): 4"
Total well Depth (ft. BTOC): 24.70
Initial (pre-installation) DTW/time: 17.78 / 10:10
Final (after pump priming) DTW/time: 17.80 / 5/11/15 09:30
Free product (circle): LNAPL/DNAPL N/A
Volume of water removed during priming (mL): -
Discharge tube length (ft.): -

Installation date/beginning time: 5/11/15 09:15
Installation date/completion time: 5/11/15 09:35
Screen Interval (ft. BTOC): - to -
Pump intake depth (ft. BTOC): variable * / 20'
Post-installation DTW/time: 17.80 / 09:40
Max. sustainable pump rate (mL/min): 100
Appearance of product: -
Discharge tube diameter (3/8" or 1/4"): 3/8"
Inlet reducer used (Y/N): N

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = - psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: Ansley / Allain
Purge date/beginning time: 5/11/15 09:10
Initial (pre-purging) DTW (ft. BTOC): 17.80
Calculated tubing + pump volume: NA

PID/FID reading (well head/background): 0.0 10.0
Purge date/completion time: 5/11/15 11:39
Final (post-purging) DTW (ft. BTOC): 18.31
No. of tubing + pump volumes purged: -

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = - psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>18</u>								<u>18</u>
Refill Setting	<u>10</u>								<u>11</u>
Discharge Setting	<u>5</u>								<u>4</u>
Flow rate (mL/min)									<u>100</u>

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
<u>09:10</u>	<u>17.80</u>								
<u>09:45</u>	<u>18.16</u>	<u>250</u>	<u>~1 L</u>	<u>20.8</u>	<u>99</u>	<u>5.39</u>	<u>286.9</u>	<u>9.07</u>	<u>3.9</u>
<u>09:55</u>	<u>18.93</u>	<u>600</u>	<u>~7 L</u>	<u>19.64</u>	<u>94</u>	<u>6.54</u>	<u>290</u>	<u>6.47</u>	<u>8.1</u>
<u>10:05</u>	<u>19.08</u>	<u>300</u>	<u>~10 L</u>	<u>19.13</u>	<u>96</u>	<u>5.30</u>	<u>301.6</u>	<u>7.18</u>	<u>9.3</u>
<u>11:15</u>	<u>18.05</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
<u>11:50</u>	<u>18.10</u>	<u>-</u>	<u>-</u>	<u>24.27</u>	<u>100</u>	<u>5.14</u>	<u>277</u>	<u>5.17</u>	<u>11.6</u>
<u>11:53</u>	<u>18.14</u>	<u>30-100</u>	<u>360</u>	<u>23.40</u>	<u>97</u>	<u>5.14</u>	<u>276.1</u>	<u>4.92</u>	<u>11.7</u>



GROUNDWATER SAMPLING FORM

00043718

Sheet 2 of 3

Water Quality Parameter Measurements (continued)

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1156	—	100	0.600	23.06	96	5.14	276.8	4.78	12.5
1159	18.15	100	0.900	23.03	96	5.14	272.6	4.72	12.6
* 1202	—	—	—	—	—	—	—	—	—
1205	18.13	100	1.200	23.59	96	5.15	280.7	4.63	13.0
1208	18.17	100	1.500	23.76	96	5.15	281.6	4.67	11.6
* 1216	18.05	—	1.500	23.84	93	5.16	280.4	4.62	6.3
1219	—	100	1.8	23.16	96	5.17	278.1	4.97	13.1
1222	18.24	100	2.1	23.07	94	5.18	278.5	4.89	12.4
1225	18.31	100	2.4	21.58	94	5.17	283.2	4.91	11.5
* 1229/1235	—	—	—	—	—	—	—	—	—
1235/1238	—	100	2.7	22.82	92	5.18	288.7	6.13	11.3
1241	18.32	100	3.0	21.22	92	5.17	288.7	6.44	11.7
1244	—	100	3.3	21.08	93	5.18	288.8	5.18	7.4

Sampling

Sampling beginning time: _____

Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: _____

Sample collection date/time: _____

Duplicate sample collected (Y/N): _____

Duplicate sample ID: _____

Split sample collected (Y/N): _____

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: * barometer measurements not very low recharge - purged down 1 pressure
air compressor kept overheating - could not stabilize
switched to bottled air.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



GROUNDWATER SAMPLING FORM

00043719

Sheet 3 of 3

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1247	18.12	100	3.6	20.02	5593	5.16	292.9	5.04	9.3
1250	—	100	3.9	19.79	93	5.16	292.7	4.80	9.4
1253	—	100	4.2	—	—	—	—	—	—
1353	12.85	—	—	—	—	—	—	—	—
1357	—	—	0	20.98	96	5.10	222.7	5.42	7.2
1400	18.24	100	8.50	20.83	95	5.11	242.2	4.87	7.9
1403	—	83	1.1	20.95	95	5.11	253.5	4.77	8.1
1406	18.16	66	1.3	21.61	94	5.12	261.4	4.77	8.3
1409	—	200	1.9	21.32	96	5.13	267.1	4.80	8.1
1412	18.31	266	2.7	20.03	94	5.12	272.1	4.78	7.9
1415	18.27	100	3.0	20.03	94	5.13	276.8	4.73	7.9
1418	—	100	3.3	21.11	94	5.14	281.0	4.74	7.6
1421	18.26	100	3.6	21.41	94	5.14	282.1	4.73	7.5

Sampling

Sampling beginning time: 1450

Sampling completion time: 1515

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1525	18.31	100	5.4	20.58	1094	5.15	291.5	4.70	7.0

Sample Information

Sample ID: LHSW68

Sample collection date/time: 1450 / 5/15

Duplicate sample collected (Y/N): N

Duplicate sample ID: —

Split sample collected (Y/N): N

Split sample ID: —

COC No(s):

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VOC - Full		3 x 100 mL			
Metals -		1 x 500 mL			
Metals - Dis		1 x 500 mL			
Microb - Fung		2 x 1 L			
Microb - Fung Dis		2 x 1 L			

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Sample Collection Log

00043720

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW69

Task: GW-MAY05

Sample Number: LHSMW69-MAY

Collection Date: 5-12-05

Sample Name: LHSMW69-MAY05-GW-REG

Collection Time: 1125

Sampling Method: SP

Start Depth: 46 ft bwc

Sample Type: GW

Sample Purpose: REG

End Depth: 46 ft bwc

Sampling Equip: Bladder Pump / QED

Sample Matrix: WATER

QC Partners:

(TB)

(ER)

(FB)

Sample Team: J Rogers J Rodriguez

Analytical Suite	Containers				Units	Type
	Flt	Frtn	Qty	Size		
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	3	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode: _____

Lot Control#: _____

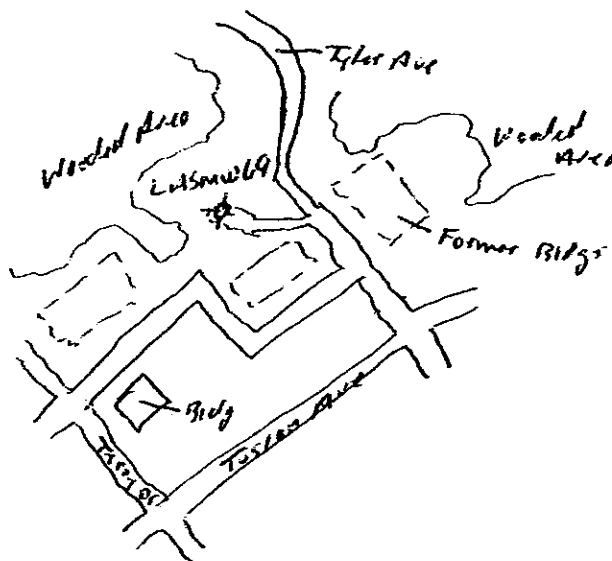
Groundwater Information:

Measured Well Depth: 51.79

Depth To Water: 12.10

Comments: Turbidity issues - fines throughout duration of pumping

Sketch Location:



Logged BY / Date: [Signature] 5/12/05

Reviewed BY / Date: _____

Sample Collection Log

00043721

Page 2 of 2

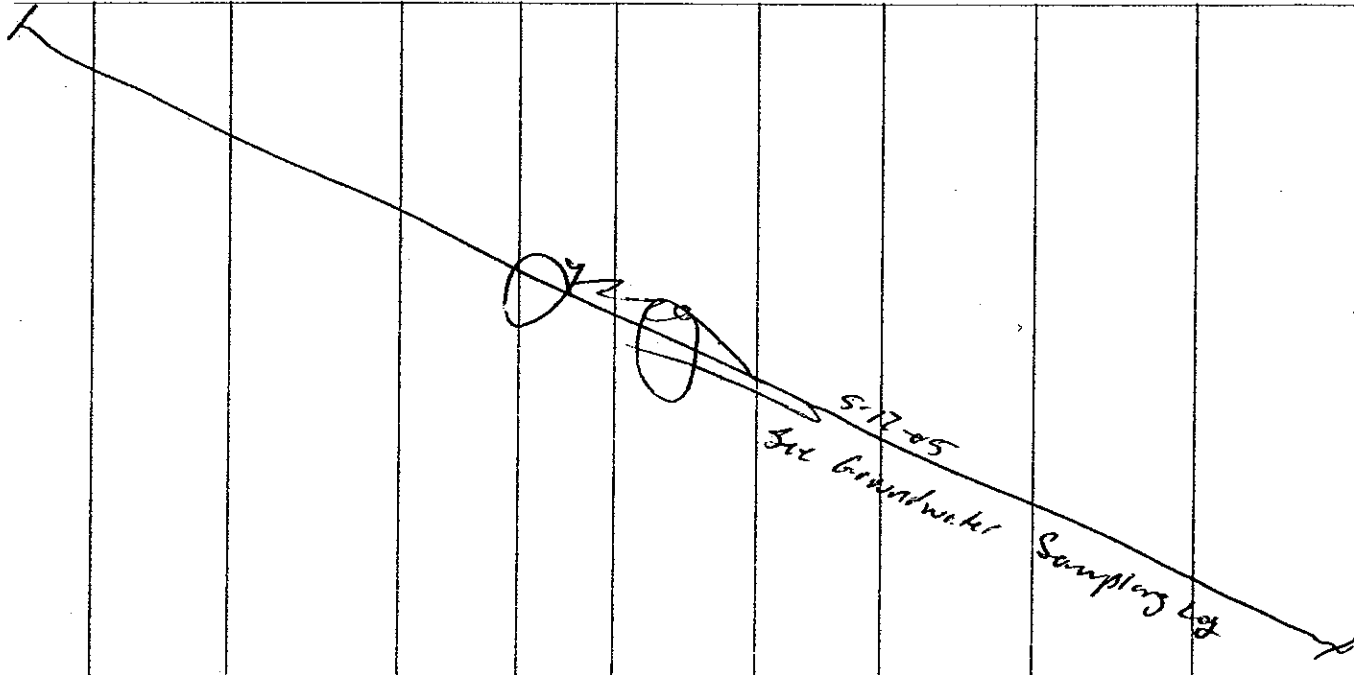
845714 - LONGHORN AAP

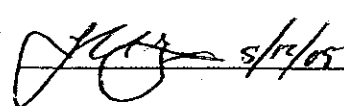
Manager: Praveen Srivastav

Location Code: LHSMW69

Sample Number: LHSMW69-MAY

PURGE RECORD:

Initial	Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
									
Sample:	1148	12.14	46.4	5.39	0.701	1.4	1.87	20.97	Final

Logged BY / Date:  5/17/05

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043722

Sheet 1 of 3

Operable Unit/Site ID: 1HAAP 35C (53)
 Project Name/ID: 545714
 Weather: HOT HUMID Partly Cloudy

Sampling location ID: LH5MN 69
 Sample ID: LH5MN 69 MAY 05
 Collection Time/Date: 5-12-05 1125

Pump Installation

Pump installation crew: Amey/Allain
 PID/FID reading (well head/background): 0.0/0.0
 Casing diameter (inches): 4
 Total well Depth (ft. BTOC): 51.79
 Initial (pre-installation) DTW/time: 20.98 / 11:04
 Final (after pump priming) DTW/time: NA
 Free product (circle): LNAPL / DNAPL
 Volume of water removed during priming (mL): NA
 Discharge tube length (ft.): 2

Installation date/beginning time: 5-12-05 1835
 Installation date/completion time: 5-12-05 0840
 Screen Interval (ft. BTOC): 41 to 51
 Pump intake depth (ft. BTOC): 46
 Post-installation DTW/time: 9148 12:14
 Max. sustainable pump rate (mL/min): NA
 Appearance of product: NA
 Discharge tube diameter (3/8" or 1/4"): 3/8
 Inlet reducer used (Y/N): NA

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: J. Rogers J. Rodriguez
 Purge date/beginning time: 0840 5-12-05
 Initial (pre-purging) DTW (ft. BTOC): 12.10
 Calculated tubing + pump volume: NA

PID/FID reading (well head/background): 0.0
 Purge date/completion time: 5-12-05 1148
 Final (post-purging) DTW (ft. BTOC): 12.14
 No. of tubing + pump volumes purged: NA

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>32</u>	<u>32</u>	<u>32</u>	<u>32</u>	<u>32</u>	<u>32</u>	<u>32</u>	<u>32</u>	
Refill Setting	<u>12</u>	<u>12</u>	<u>12</u>	<u>12</u>	<u>12</u>	<u>12</u>	<u>12</u>	<u>12</u>	
Discharge Setting	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>3</u>	
Flow rate (mL/min)	<u>220</u>	<u>220</u>	<u>205</u>	<u>205</u>	<u>205</u>	<u>205</u>	<u>230</u>	<u>230</u>	

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
<u>0843</u>	<u>12.14</u>	<u>220</u>	<u>1.66</u>	<u>19.05</u>	<u>0.696</u>	<u>5.57</u>	<u>79.6</u>	<u>7.79</u>	<u>559</u>
<u>0846</u>	<u>12.14</u>	<u>220</u>	<u>1.32</u>	<u>18.94</u>	<u>0.696</u>	<u>5.55</u>	<u>77.3</u>	<u>7.72</u>	<u>49.0</u>
<u>0849</u>	<u>12.14</u>	<u>205</u>	<u>1.93</u>	<u>19.75</u>	<u>0.697</u>	<u>5.51</u>	<u>83.7</u>	<u>7.20</u>	<u>388</u>
<u>0852</u>	<u>12.12</u>	<u>205</u>	<u>2.54</u>	<u>18.74</u>	<u>0.697</u>	<u>5.49</u>	<u>82.6</u>	<u>7.06</u>	<u>65.5</u>
<u>0855</u>	<u>12.12</u>	<u>205</u>	<u>3.15</u>	<u>18.70</u>	<u>0.696</u>	<u>5.47</u>	<u>78.4</u>	<u>6.90</u>	<u>64.6</u>
<u>0858</u>	<u>12.12</u>	<u>205</u>	<u>3.76</u>	<u>18.69</u>	<u>0.697</u>	<u>5.49</u>	<u>75.9</u>	<u>5.57</u>	<u>41.4</u>
<u>0901</u>	<u>12.12</u>	<u>230</u>	<u>4.37</u>	<u>18.75</u>	<u>0.704</u>	<u>5.42</u>	<u>72.5</u>	<u>5.22</u>	<u>63.9</u>
<u>0904</u>	<u>12.12</u>	<u>230</u>	<u>4.98</u>	<u>18.75</u>	<u>0.705</u>	<u>5.43</u>	<u>73.4</u>	<u>5.22</u>	<u>58.4</u>



GROUNDWATER SAMPLING FORM

00043723

Sheet 2 of 3

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0907	12.14	230	5.67	18.79	0.704	5.38	71.9	5.08	54.1
0910	12.14	230	6.36	18.79	0.705	5.38	72.3	5.07	44.6
0913	12.14	230	7.05	18.82	0.704	5.39	71.2	4.97	37.4
1013	12.14	100	8.05	17.92	0.702	5.41	57.5	1.97	17.6
1033	12.14	100	8.05	20.10	0.704	5.34	58.3	1.75	14.4
1040	12.14	100	16.75	20.52	0.704	5.36	54.2	1.77	15.2
1047	12.14	100	17.45	20.56	0.704	5.37	54.2	1.78	15.8
1050	12.14	100	17.75	20.59	0.704	5.37	54.1	1.79	14.1
1053	12.14	100	18.05	20.67	0.704	5.37	53.9	1.81	13.6
1056	12.14	100	18.35	20.59	0.703	5.37	53.7	1.82	10.3
1059	12.14	100	18.65	20.72	0.703	5.37	53.7	1.86	10.9
1102	12.14	100	18.95	20.62	0.702	5.37	53.4	1.86	10.8
1105	12.14	100	19.25	20.61	0.703	5.37	53.3	1.87	10.1
1108	12.14	100	19.55	20.66	0.703	5.37	53.1	1.87	10.2

Sampling

Sampling beginning time: 1110

Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: _____

Sample collection date/time: _____

Duplicate sample collected (Y/N): _____

Duplicate sample ID: _____

Split sample collected (Y/N): _____

Split sample ID: _____

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: Dump flow cell @ 0858. Dump flow cell @ 0913. Reduce pressure to obtain 100 mL/min. Dump flow cell @ 0923. No reading between 0913 & 1013. Readings not to be taken until turbidity approaches 10 NTU or falls below.

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



GROUNDWATER SAMPLING FORM

00043724

Sheet 3 of 3

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1111	12.14	100	19.85	20.58	0.702	5.37	52.9	1.91	9.8
1114	12.14	100	20.15	20.88	0.702	5.37	52.8	1.90	10.0
1117	12.14	100	20.45	20.69	0.702	5.34	52.5	1.90	9.7
1120	12.14	100	20.75	20.72	0.702	5.39	51.4	1.91	9.6
1123	12.14	100	20.69	20.77	0.702	5.39	51.2	1.93	9.5

Sampling

Sampling beginning time: 1125

Sampling completion time: _____

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1125	12.14	100	20.89	20.82	0.702	5.37	53.4	1.92	9.2
1149	12.14	100	Final	20.97	0.701	5.39	46.4	1.87	1.4

Sample Information

Sample ID: LH5PW69MAV05

Sample collection date/time: 5-12-05 1125

Duplicate sample collected (Y/N): NO

Duplicate sample ID: N/A

Split sample collected (Y/N): NO

Split sample ID: N/A

COC No(s): _____

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
VOL	Bladder				
Metals - W	Bladder				
Metals - As	Bladder				
Organic - Furan	Bladder				
Organic - DIS	Bladder				

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

Sample Collection Log

00043725

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: **LHSMW70**

Sample Number: **LHSMW70-MAY**

Sample Name: **LHSMW70-MAY05-GW-REG**

Sampling Method: **SP**

Sample Type: **GW**

Sample Purpose: **REG**

Sampling Equip: QED blower pump

QC Partners:

(TB)

(ER)

(FB)

Task: **GW-MAY05**

Collection Date: 5/12/15

Collection Time: 09:10

Start Depth: 14.78

End Depth: 14.90

Sample Matrix: **WATER**

Sample Team: Ansly / Allam

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Containers						
Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

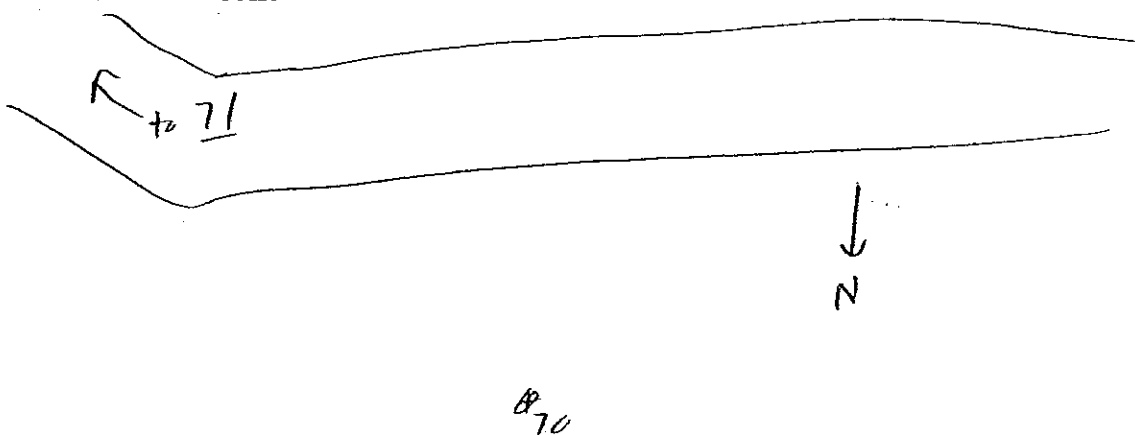
Groundwater Information:

Measured Well Depth: 24.43

Depth To Water: 11.80

Comments: _____

Sketch Location:



Logged BY / Date: _____

Reviewed BY / Date: _____

Sample Collection Log

00043726

Page 2 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

Location Code: LHSMW70

Sample Number: LHSMW70-MAY

PURGE RECORD:

Initial	Time(24hr)	Depth to Water (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
---------	------------	------------------------	------------	------------	-------------------------	--------------------	---------------------	--------------------	-----------------------

See Purging Form

→ Sample:	1040	14.90	214.6	7.86 7.77	227	-2.5	0.48	21.53	9.2
-----------	------	-------	-------	-------------------------	-----	------	------	-------	-----

Logged BY / Date: _____

Reviewed BY / Date: _____



GROUNDWATER SAMPLING FORM

00043727

Sheet 1 of 2

Operable Unit/Site ID: LHAPP 35C Sampling location ID: LHAPP 70
Project Name/ID: LHAPP 645714 Sample ID: LHAPP 70-14503
Weather: 1/c ~80°F Collection Time/Date: 0940 / 5/12/15

Pump Installation

Pump installation crew: Ansley / Allain Installation date/beginning time: 5/11/15 / 1640
PID/FID reading (well head/background): 475 ppb / 0.02 EL Installation date/completion time: 5/11/15 / 1700
Casing diameter (inches): 4" Screen Interval (ft. BTOC): 11 to 21
Total well Depth (ft. BTOC): 24.43 Pump intake depth (ft. BTOC): 16'
Initial (pre-installation) DTW/time: 11.80 / (1026) Post-installation DTW/time: 11.48 /
Final (after pump priming) DTW/time: 12.53 / 0840 Max. sustainable pump rate (mL/min):
Free product (circle): ENAPL / DNAPL Appearance of product:
Volume of water removed during priming (mL): Discharge tube diameter (3/8" or 1/4"):
Discharge tube length (ft.): Inlet reducer used (Y/N):

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: Ansley / Allain PID/FID reading (well head/background): 0.0 / 0.0
Purge date/beginning time: 5/12/15 0834 Purge date/completion time: 5/12/15 / 0938
Initial (pre-purging) DTW (ft. BTOC): 4.98 / 11.78 Final (post-purging) DTW (ft. BTOC): 14.78
Calculated tubing + pump volume: NA No. of tubing + pump volumes purged:

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	<u>15</u>	<u>10</u>	<u>10</u>	<u>12</u>	<u>11</u>	<u>11</u>			<u>11</u>
Refill Setting	<u>10</u>	<u>9</u>	<u>6</u>	<u>8</u>	<u>8</u>	<u>6</u>			<u>6</u>
Discharge Setting	<u>5</u>	<u>6</u>	<u>7</u>	<u>7</u>	<u>8</u>	<u>9</u>			<u>9</u>
Flow rate (mL/min)	<u>300</u>	<u>200</u>	<u>115</u>	<u>200</u>	<u>200</u>	<u>130</u>			<u>100</u>

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
<u>0840</u>	<u>12.53</u>	<u>—</u>	<u>—</u>	<u>19.95</u>	<u>228</u>	<u>4.91</u>	<u>235.1</u>	<u>2.07</u>	<u>-2.3</u>
<u>0843</u>	<u>12.74</u>	<u>300</u>	<u>900</u>	<u>19.65</u>	<u>226</u>	<u>4.89</u>	<u>243</u>	<u>1.07</u>	<u>-2.2</u>
<u>0846</u>	<u>12.97</u>	<u>200</u>	<u>1.500</u>	<u>19.77</u>	<u>225</u>	<u>4.88</u>	<u>250</u>	<u>0.79</u>	<u>-2.1</u>
<u>0849</u>	<u>13.05</u>	<u>115</u>	<u>1.850</u>	<u>20.29</u>	<u>225</u>	<u>4.87</u>	<u>253</u>	<u>0.73</u>	<u>-2.2</u>
<u>0852</u>	<u>13.20</u>	<u>100</u>	<u>2.150</u>	<u>20.79</u>	<u>225</u>	<u>4.88</u>	<u>253.5</u>	<u>0.66</u>	<u>-2.1</u>
<u>0855</u>	<u>13.36</u>	<u>200</u>	<u>2.750</u>	<u>20.37</u>	<u>226</u>	<u>4.88</u>	<u>254.7</u>	<u>0.63</u>	<u>-2.0</u>
<u>0858</u>	<u>13.52</u>	<u>215</u>	<u>3.400</u>	<u>20.03</u>	<u>225</u>	<u>4.87</u>	<u>255.4</u>	<u>0.58</u>	<u>-2.2</u>
<u>0901</u>	<u>13.74</u>	<u>200</u>	<u>4.000</u>	<u>20.13</u>	<u>225</u>	<u>4.87</u>	<u>255.9</u>	<u>0.52</u>	<u>-2.1</u>



GROUNDWATER SAMPLING FORM

00043728

Sheet 2 of 2

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0904	13.89	200	4.600	19.91	225	4.87	256.2	0.50	-2.1
0907	14.19	260	5.400	19.59	224	4.87	256.6	0.416	-2.1
0910	14.26	200	6.000	19.69	224	4.86	256.7	0.415	-2.0
0913	14.33	160	6.500	20.03	223	4.87	256.4	0.415	-2.1
0916	14.41	130	6.900	20.55	223	4.87	256.7	0.415	-2.1
0919	14.47	130	7.300	20.81	224	4.87	255.3	0.415	-2.1
0922	14.56	130	7.700	21.16	224	4.88	254.9	0.417	-2.1
0925	14.61	100	8.000	21.40	224	4.88	254.4	0.417	-2.2
0928	14.57	100	8.300	21.46	224	4.88	253.7	0.416	-2.2
0931	14.68	100	8.600	21.58	224	4.88	253	0.416	-2.2
0934	14.73	100	8.900	21.74	223	4.88	253	0.416	-2.1
0937	14.78	100	9.200	21.84	223	4.88	252.5	0.415	-2.1

Sampling

Sampling beginning time: 0910

Sampling completion time: 1030

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
0937	14.78	100	9.2	21.84	223	4.88	252.5	0.415	-2.1
1010	14.90	100	—	21.53	227	4.86	248.6	0.418	-2.5

Sample Information

Sample ID: LHSM-70

Sample collection date/time: 5/12/09 0940

Duplicate sample collected (Y/N): N

Duplicate sample ID: N/A

Split sample collected (Y/N): N

Split sample ID: N/A

COC No(s):

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers
<u>Ammonia</u>					
<u>Ammonia Nitrate</u>					
<u>Volatiles</u>					
<u>Nitrate</u>					
<u>Nitrite</u>					

Comments:

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter



Shaw E & I, Inc.

Sample Collection Log

00043729

Page 1 of 1

845714 - Longhorn Army Ammunition Plant

Manager: Praveen Srivastav

RFA / COC Number:

Location Code: LHSMW71

Task: GW-MAY05

Sample Number: LHSMW71-MAY05

Collection Date: 5/14/05

Sample Name: LHSMW71-MAY05-D-GW-FD

Collection Time:

Sampling Method: SP

Start Depth:

Sample Type: GW

Sample Purpose: FD

End Depth:

Sampling Equip:

Sample Matrix: WATER

QC Partners:

Sample Team:

(TB)

(ER)

(FB)

Analytical Suite	Containers					
	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode:

Lot Control#:

Groundwater Information:

Measured Well Depth: 19.50 Depth To Water: 12.86

Comments:

Sketch Location:

Logged BY / Date:

Reviewed BY / Date:



Shaw E & I, Inc.

Sample Collection Log

00043730

Page 1 of 2

845714 - LONGHORN AAP

Manager: Praveen Srivastav

RFA / COC Number: _____

Location Code: LHSMW71

Sample Number: LHSMW71-MAY

Sample Name: LHSMW71-MAY05-GW-REG

Sampling Method: SP

Sample Type: GW

Sample Purpose: REG

Sampling Equip: _____

Task: GW-MAY05

Collection Date: _____

Collection Time: _____

Start Depth: _____

End Depth: _____

Sample Matrix: WATER

QC Partners: _____

(TB) _____

(ER) _____

(FB) _____

Sample Team: _____

Containers

Analytical Suite	Flt	Frtn	Qty	Size	Units	Type
VOC-FULL	N	A	3	40	mL	VOA VIAL
METALS-W	N	B	1	1000	mL	HDPE
METALS-DIS	N	C	1	1000	mL	HDPE
Dioxins-Furans	N	D	2	1	L	Amb. Glass
Dioxins-Fur-DIS	N	E	2	1	L	Amb. Glass

ERPIMS Values:

Sacode: _____

Lot Control#: _____

Groundwater Information:

Measured Well Depth: _____

Depth To Water: _____

Comments: _____

Sketch Location: _____

Logged BY / Date: _____

Reviewed BY / Date: _____



845714 - LONGHORN AAP

Manager: Praveen Srivastav

Page 2 of 2

Location Code: LHSMW71

Sample Number: LHSMW71-MAY

Initial Time(24hr)	DepthtoWater (ft)	Eh (mV)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DissOxygen (ppm)	Temperature (C)	Purge Volume (gal)
--------------------	----------------------	------------	------------	-------------------------	--------------------	---------------------	--------------------	-----------------------

	(g)	(ml)	(mole/l)	(M)	(N)	(ppm)	(C)	(gal)
Sample:								

Logged BY / Date: _____

Reviewed BY / Date:



GROUNDWATER SAMPLING FORM

00043732

Sheet 1 of 1

5/13/15

Operable Unit/Site ID: _____	Sampling location ID: <u>LHSH-71</u>
Project Name/ID: <u>LHSH</u>	Sample ID: _____
Weather: _____	Collection Time/Date: _____

Pump Installation

Pump installation crew: _____	Installation date/beginning time: <u>5/11/15/1700</u>
PID/FID reading (well head/background): <u>0.0 10.0</u>	Installation date/completion time: <u>5/11/15/</u>
Casing diameter (inches): <u>4"</u>	Screen Interval (ft. BTOC): _____ to _____
Total well Depth (ft. BTOC): <u>19.50</u>	Pump intake depth (ft. BTOC): <u>17'</u>
Initial (pre-installation) DTW/time: <u>12.86 / 10:35</u>	Post-installation DTW/time: <u>12.78 / 17:15</u>
Final (after pump priming) DTW/time: <u>12.48 13.05</u>	Max. sustainable pump rate (mL/min): _____
Free product (circle): <u>-LNAPL/DNAPL</u>	Appearance of product: _____
Volume of water removed during priming (mL): _____	Discharge tube diameter (<u>3/8"</u> or 1/4"): _____
Discharge tube length (ft.): _____	Inlet reducer used (Y/N): _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)									
Refill Setting									
Discharge Setting									
Flow rate (mL/min)									

Purging

Purging/sampling crew: <u>Ansley / Al/lu</u>	PID/FID reading (well head/background): <u>0.0 10.0</u>
Purge date/beginning time: <u>5/12/15 1115</u>	Purge date/completion time: <u>1300 5/12/15</u>
Initial (pre-purging) DTW (ft. BTOC): <u>12.98</u>	Final (post-purging) DTW (ft. BTOC): <u>5/13/15/110/12.8</u>
Calculated tubing + pump volume: <u>NA</u>	No. of tubing + pump volumes purged: _____

Pneumatic Controller Tuning:

Initial air pressure = H (ft.) X 0.43 = _____ psi

	Initial	2	3	4	5	6	7	8	Final
Pressure (psi)	15	11	10	10					
Refill Setting	10	8	6	5					
Discharge Setting	5	7	9	10					
Flow rate (mL/min)	350	330	~150						

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1120	13.34	Flow	6.11	21.31	1,460	5.69	188.4	1.94	79.0
1123	13.54	330	1,000	20.90	1,446	5.67	186.1	1.08	61.4
1126	13.74	330	2.0	20.91	1,446	5.67	184.1	0.79	52.1
1129	13.96	175	2.550	21.47	1,438	5.68	182.3	1.22	40.8
1132	14.25	145	2.73,000	21.74	1,440	5.68	182.2	1.08	35.1
1135	14.20	130	3.400	22.73	1,433	5.69	181.5	0.93	34.1
1138	14.31	115	3.750	23.09	1,439	5.70	180.3	1.01	29.2
1141	14.38	66	3.950	23.64	1,438	5.69	180.3	0.75	27.9



GROUNDWATER SAMPLING FORM

00043733

Sheet of

Water Quality Parameter Measurements (continued)									
Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)
1144	14.47	80	4.2	24.86	1,441	5.70	180.4	0.73	26.7
1147	14.54	100	4.5	25.40	1,440	5.71	180.4	0.74	29.2
1150	14.64	80	4.75	25.93	1,433	5.70	180.9	0.74	23.4
1153	14.70	80	4.900	26.12	1,432	5.71	182.8	0.71	21.2
1156	14.74	80	5.100	26.43	1,427	5.71	182.5	0.72	20.0
1159	14.86	100	5.400	27.01	1,422	5.71	182.4	0.71	18.6
1202	14.93	80	5.65	27.14	1,420	5.71	182.0	0.73	19.2
1205	15.01	60	5.85	27.26	1,414	5.71	182.3	0.72	17.9
1208	15.06	80	6.100	27.37	1,409	5.71	182.5	0.72	15.3
1211	15.25	180	6.500						

Sampling

Sampling beginning time: 1300 Sampling completion time:

Water Quality Parameter Measurements

Time	DTW (ft. BTOC)	Purge Rate (mL/min)	Cumulative Volume Purged (L)	Temp. (degree C)	Electrical Conductivity (uMhos/cm)	pH	Eh (mv)	DO (mg/L)	Turbidity (NTU)

Sample Information

Sample ID: Sample collection date/time:
 Duplicate sample collected (Y/N): Yes Duplicate sample ID:
 Split sample collected (Y/N): Yes Split sample ID:
 COC No(s):

Requested Analysis	Method	Containers	Requested Analysis	Method	Containers

Comments: no lock on 5/13/15 Sample - 1 Perizaltis
1215 switched to straight purge - will sample in 23 hrs 5/13/15
day 0 1300 (1' water)

Abbreviations: BTOC - Below top of casing; DTW - Depth to water; H - head above pump intake; mL - milliliter; L - Liter

5/13/05

By _____ Date _____ Subject _____

Sheet No. 1 of 2

Chkd. By _____ Date _____

Proj. No. _____

25 in. X 25 in.

piezometer ~~1118~~ @ 35C
 1118
 $17.17 = 16.65$
 $17.17 = 21.96$

16.46
 16.65
 5.31

column = 5.31'

$.5$
 $.5$
 $.25$
 $.25$
 1570
 6280
 $.7650$

4
 6
 2
 5
 7
 3
 7
 4
 2
 00694
 $.785$
 03470
 055520
 0485800
 0054479.0

$.785 \text{ in}^2$
 $.00694$

2
 2
 5.31
 1785
 2655
 12480
 371700
 416835

005

4.17

begin purge @ 1140

5.31
 $.005$
 $.02655$

$.026$
 3
 $.078$

$.078 \text{ ft}^3$
 3
 3
 6
 7.48
 $.078$
 5984

purge 0.6 gallons

$.58$

Parameters

begin
 and
 purge

	Temp	pH	Cond	NO	ORP	Turb
1144	26.32	6.41	3.383	7.21	120.1	5.9
1215	23.45	6.32	3.227	4.41	185.4	10.1

52360
 5834.4

sample 1215



Shaw Environmental & Infrastructure, Inc.

Piezometer Sampling

00043735

5/13/05

By _____ Date _____ Subject _____

Sheet No. 2 of 2

Chkd. By _____ Date _____

Proj. No. _____

.25 in. X .25 in.

13550 Piezometer [redacted] DTN = 1355
ID = 20.00'

6.45' column

7.65 m²

.005

6.45'

.005

0.3225

0.32

3

0.96

4.7
7.48

.096

1.4788

6732.8

716.08

0.72 gallons

14105 begin purging

purge 0.75 gallons

14115 parameters

Temp	pH	Cond	ORP	DO	Turbidity
23.51	5.72	495 m	215.9	5.29	431.0

14120 collect sample

Piezometer [redacted]

14135 - DTN = 14141
ID = 22.90

12.80

14.44

7.96

7.96' column

7.96

.005

0.7980

.04

3

.12

7.48

1.2

11196

7480

8976

0.9

purge time 14147-

purge 1.0 gallon

parameters
14152

Temp	pH	Cond	ORP	DO	Turbidity
22.64	5.61	0.358	224.4	6.38	92.2

sample time = 1310

Appendix C

Baseline Risk Assessment for Residential Use of LHAAP-48

Table of Contents

List of Tables	ii
List of Figures	ii
List of Attachments	ii
Acronyms and Abbreviations	iii
1.0 Introduction	1-4
2.0 Data Evaluation	2-1
2.1 Evaluation of Analytical Methods	2-1
2.2 Summary of Sampling Efforts	2-1
2.3 Data Reduction	2-1
2.4 Evaluation of Dioxins and Furans	2-2
2.5 Identification of Chemicals of Potential Concern	2-3
2.5.1 Comparison of Metals to LHAAP-Specific Background Concentrations in Soil	2-4
2.5.1.1 Statistical Distribution Tests	2-4
2.5.1.2 Statistical Comparisons	2-6
2.5.1.3 Geochemical Evaluations	2-6
2.5.2 Organic Chemicals in Soil	2-7
2.6 Summary	2-8
3.0 Exposure Assessment	3-1
3.1 Land and Water Uses	3-1
3.2 Site Conceptual Model	3-2
3.3 Exposure Factors	3-4
3.3.1 Identification of Exposure-Point Concentrations	3-4
3.4 Identification of Exposure Models and Assumptions	3-4
3.4.1 Ingestion Exposure to COPCs in Soil	3-5
3.4.2 Inhalation Exposures to COPCs in Soil	3-5
3.4.2.1 Volatilization Factor	3-7
3.4.3 Dermal Exposures to COPCs in Soil	3-8
4.0 Toxicity Assessment	4-1
4.1 Carcinogenic Effects	4-1
4.2 Noncarcinogenic Effects	4-2
5.0 Risk Characterization	5-1
5.1 Carcinogenic Effects Of Chemicals	5-1
5.2 Noncancer Effects of Chemicals	5-2
5.3 Risks Associated With Exposure to Soil	5-3
6.0 Uncertainty Analysis	6-1
7.0 References	7-1

List of Tables

Table C-1	Soil Samples, LHAAP-48
Table C-2	2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP-48
Table C-3	Occurrence, Distribution, and Selection of Chemicals of Potential Concern (COPC), Soil, LHAAP-48
Table C-4	Comparison of Metal Concentrations in LHAAP-48 Soil Samples to Background Concentrations
Table C-5	Exposure Factors Used to Estimate Intake of Chemicals of Potential Concern, LHAAP-48 Site
Table C-6	Toxicity Values for Chemicals of Potential Concern, Baseline Risk Assessment for the LHAAP-48 Site
Table C-7a	Incremental Lifetime Cancer Risk (ILCR) for Potential Ingestion Exposure of Future Residents to Chemicals from Soil at the LHAAP-48 Site
Table C-7b	Hazard Index (HI) for Potential Ingestion Exposure of Future Residents to Chemicals from Soil at the LHAAP-48 Site
Table C-8a	Incremental Lifetime Cancer Risk (ILCR) for Potential Inhalation Exposure of Future Resident to Airborne Chemicals from Soil at the LHAAP-48 Site
Table C-8b	Hazard Index (HI) for Potential Inhalation Exposure of Future Resident to Airborne Chemicals from Soil at the LHAAP-48 Site
Table C-9a	Incremental Lifetime Cancer Risk (ILCR) for Potential Dermal Exposure of Future Residents to Chemicals from Soil at the LHAAP-48 Site
Table C-9b	Hazard Index (HI) for Potential Dermal Exposure of Future Residents to Chemicals from Soil at the LHAAP-48 Site
Table C-10a	Exposures and Incremental Lifetime Cancer Risks for Potential Exposure of Future Resident to Soil at the LHAAP-48 Site
Table C-10b	Exposures and Noncancer Hazards for Potential Exposure of Future Resident to Soil at the LHAAP-48 Site

List of Figures

Figure C-1	LHAAP-48 Sample Location Map
------------	------------------------------

List of Attachments

Attachment 1	Statistical Comparison to Background Concentrations
Attachment 2	Geochemical Evaluation of Concentrations of Metals in Soil LHAAP-48

Acronyms and Abbreviations

ABS _d	dermal absorption factor
ABS _{GI}	gastrointestinal absorption factor
Bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm ²	centimeter square
cm ³	cubic centimeters
COPCs	Chemicals of Potential Concern
CSEM	conceptual site exposure model
g	gram
IRIS	integrated risk information system
LHAAP	Longhorn Army Ammunition Plant
m	meter
MCL	maximum contaminant levels
MDC	maximum detected concentrations
MSC	medium specific concentration
µg/m ³	micrograms per cubic meter
mg/kg	milligrams per kilogram
MLE	most likely exposure
MSSLs	medium-specific screening levels
ng/kg	nanograms per kilogram
RBSV	risk-based screening values
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
sec	second
SF	slope factor
Shaw	Shaw Environmental, Inc.
STC	source-term concentration
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
TEF	toxicity equivalency factor
TEQ	toxicity equivalent quotient
UCL	upper confidence limit
UPL	upper prediction limit
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UTL	upper tolerance limit

1.0 Introduction

This residential risk assessment for LHAAP-48, prepared by Shaw Environmental, Inc. (Shaw) for the U.S. Army Corps of Engineers (USACE), Tulsa District, under Total Environmental Restoration Contract DACA56-94-D-0020, Task Order 0109, describes the risk associated with residential use of LHAAP-48, Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. The results of this assessment will be used to support decisions related to future use of soil at LHAAP-48 (**Figure C-1**). Environmental sampling and analysis efforts were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

The assessment of potential risk to current trespassers and future maintenance workers for exposure to chemicals in soil at LHAAP-48 in a hypothetical industrial scenario have been reported as acceptable by Jacobs in 2003. Estimated risk from potential groundwater ingestion by industrial workers was unacceptable and predominantly associated with thallium and dioxins, with lesser contributions from tetrachloroethene and trichloroethene (TCE). Antimony, arsenic, chromium, thallium, TCE, and bis(2-ethylhexyl)phthalate exceeded their respective maximum contaminant levels (MCLs) established by the Safe Drinking Water Act (Jacobs, 2003). Experience at other sites has shown that metals and dioxin concentrations in groundwater can be elevated due to high turbidity of the sample. Because of the uncertainty of these analysis results, additional samples were taken by Shaw in 2004 and 2005 using low-flow sampling methods to help ensure that samples have low turbidity (Shaw, 2004a, 2005).

The environmental data used in the Jacobs (2003) industrial risk assessment, entitled Draft Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, that includes LHAAP-48 and additional groundwater data gathered by Shaw in 2004, 2005, and 2006 (see main volume, Section 2.0) were evaluated to supplement the industrial risk assessment (Jacobs, 2003) and provide risk managers information about the suitability of the site for hypothetical residential use. This baseline risk assessment for use of LHAAP-48 as a residential site follows guidance from the U.S. Environmental Protection Agency (USEPA) (1989;1992a,b,c;2002a,b) and the Texas Commission on Environmental Quality (TCEQ) (TCEQ, 1998, 2001, 2003, and 2004).

Because chemicals that contributed to health risk from groundwater used in previous assessments (Jacobs, 2003) were either not detected or were below maximum contaminant level (MCL) values when collected by low-flow groundwater sampling methods, risk from hypothetical residential use of the site was assessed only for exposure to chemicals detected in soil.

Figures and tables that support this appendix are presented at the end of the text portion. There are two attachments that follow the figures and tables: **Attachment 1, Statistical Comparison to Background Concentrations**; and **Attachment 2, Geochemical Evaluation of Soil Concentrations of Metals in Soil at LHAAP-48**.

2.0 *Data Evaluation*

Chemicals of potential concern (COPCs) for this evaluation were identified by comparing the results of chemical concentrations in soil (Jacobs, 2003) to LHAAP background concentrations, risk-based screening values, and other criteria.

2.1 *Evaluation of Analytical Methods*

Soil and water samples were analyzed according to USEPA methods (USEPA, 1983, 1992a). Evaluation of analytical data reported before June 2002 was described in the industrial risk assessment (Jacobs, 2003). After June 2002, additional groundwater samples were collected and analyzed as described in the work plans for LHAAP sites (Shaw, 2004a,b) and in this section.

2.2 *Summary of Sampling Efforts*

Soil and groundwater samples were collected between 1993 and 2005. Because no surface water bodies are located within the LHAAP-48 boundary, no surface water or sediment samples have been collected; samples collected from the surface ditch and drainage area were evaluated as soil samples in the industrial risk assessment (Jacobs, 2003).

Soil samples from LHAAP-48 were collected from depths less than 15 feet below ground surface (bgs) during three phases of a remedial investigation (RI) effort conducted from 1993 through 1998 (Jacobs, 2003). Soil samples were taken from 14 soil borings located adjacent to the 12 sump locations in the Phase I RI of 1993. In 1994 and 1995, the Phase II RI included installation of five monitoring wells and collection of soil and groundwater samples at those locations. Additional soil samples were collected, including samples from the surface ditch and drainage area in the Phase II RI (Jacobs, 2003). Two rounds of sampling were conducted at the 5 monitoring wells in 1996. The Phase III RI conducted in 1998 involved collection of soil samples near the sump locations and from an additional soil boring. Groundwater samples were collected from the five monitoring wells in the Phase III RI. Five were installed in the shallow subsurface that range from 18 to 28 ft bgs (Jacobs, 2003). One well (48WW01) was installed as an intermediate-depth well in 2004 (Shaw, 2004a, 2005). These six wells at LHAAP-48 (**Figure C-1**) were sampled in September 2004 and May 2005, as described in **Section 2.1** of the main text.

2.3 *Data Reduction*

Analytical data were evaluated as follows:

- Samples with all validation qualifiers were included in the residential risk assessment except for “R”-qualified data, which were rejected from the data set

- “J”- qualified data were included as detected concentrations
- “E”- qualified data were included as detected concentrations
- “B”- qualified data were treated as non-detected concentrations
- All non-detected concentrations were assigned a value equal to half the reporting limit.

A more detailed discussion of data qualifiers and their interpretation is given in the work plan (Shaw, 2004b).

The soil samples analyzed are presented in **Table C-1**. Fifty-one soil samples from 19 locations were evaluated. Duplicates were collected for seven samples for analytical quality control purposes (**Table C-1**), and the average concentration was evaluated as a single sample.

Chemicals detected in groundwater that contributed to health risk and hazard in previous assessments (Jacobs, 2003) were either not detected or were below MCLs when analyzed in groundwater collected by low-flow methods (see **Section 2.1** of the main text). The detection of chromium in one shallow well, which marginally exceeded the MCLs concentration, was believed to be associated with sediments and with corroded well construction materials. This hypothesis was tested by installing a new well (MW48WW02) having poly vinyl chloride (PVC) casing material, at the location of maximum chromium groundwater concentration. Groundwater from this well was shown to have chromium concentrations below the MCL (see **Section 2.2** of the main text). Because these results do not indicate of risk associated with groundwater at LHAAP-48, they are not considered further in the COPC selection.

2.4 Evaluation of Dioxins and Furans

Dioxins and furans were evaluated using the 2,3,7,8-TCDD toxicity equivalency (TEQ) approach. Individual congener concentrations were multiplied by toxicity equivalency factors recommended by Van den Berg et al. (1998), and then summed to describe a 2,3,7,8-TCDD TEQ concentration for each sample (**Table C-2**).

A total of 16 samples, 2 samples collected at 0 – 0.5 feet and 3 – 5 feet bgs from SUMP094, SUMP095, SUMP098, SUMP100, WRSUMP001, and WRSUMP003; and 4 samples (including one QC sample) collected at 0 – 0.5, 1 – 3, and 3 – 5 feet at boring 48SB01 were analyzed for dioxins/furans. Results of dioxins analysis were reported in the RI (Jacobs, 2002) and are shown in **Table C-2**. The concentrations reported as not detected (U-qualified) are shown in **Table C-2** as one-half of the reporting limit given in RI report. The value for the sample from 1 - 3 ft bgs at 48SB01 is the average of nondetected concentration (<0.124 ng/kg) and duplicate sample concentration (0.284 ng/kg).

2.5 Identification of Chemicals of Potential Concern

The COPCs were identified as chemicals that were detected at concentrations above one or more highly conservative criteria designed to eliminate from further evaluation those chemicals that are unlikely to cause adverse effects.

The COPCs for the residential risk assessment were identified using the following criteria:

- **Essential human nutrients** (calcium, chloride, iron, magnesium, phosphorus, potassium, and sodium) were eliminated as COPCs (TCEQ, 2001, 2003).
- **Risk-Based Screening.** A risk-based screening step was used to identify chemicals that would contribute significantly to human health risk. Chemicals with maximum detected concentrations (MDC) equal to or below risk-based screening concentrations were eliminated from further evaluation. The TCEQ risk-based screening values (RBSV) were used in this step (TCEQ, 2004). The RBSVs are concentrations that are protective of human health exposure via ingestion, inhalation, and dermal absorption pathways at a 1E-06 target risk level for carcinogens and a 0.1 target hazard quotient for noncarcinogens. Where contaminants have both cancer and noncancer toxicity factors, the RBSV represents the lower (i.e., more conservative) value. The RBSVs are protective of residential land-use scenarios. When an RBSV was not available for a chemical, other sources were consulted to develop risk-based screening concentrations such as the USEPA Region 6 medium-specific screening levels (MSSLs) (USEPA, 2004).
- **Frequency of Detection.** Chemicals were eliminated as COPCs if they were detected infrequently (5 percent or lower frequency of detection) at low levels, providing that at least 20 samples were analyzed for the chemical and the chemical is not known to be associated with site operations (TCEQ, 1998; USEPA, 1989). Chemicals detected infrequently, but at high concentrations, were retained in the evaluation unless their exclusion could be justified based on site process information or historical data.
- **Comparison to Background.** Concentrations of chemicals were compared to background concentrations specific to LHAAP by statistical methods and geochemical evaluations. The geochemical evaluations serve as an independent check of the statistical comparisons.

Results of soil analysis were evaluated as described above to provide the following characteristics of the data set (**Table C-3**):

- Number of samples, number of detects, number of non-detects, frequency of detection
- Minimum and maximum reporting limits

- Minimum and maximum detected values
- Mean, median, and standard deviation, as appropriate for the distribution
- 95 percent upper confidence limit (95% UCL) of the mean or median, as appropriate for the distribution
- 95 percent upper tolerance limit with 95 percent confidence (95%/95% UTL)
- 95 percent upper prediction limit (95% UPL).

2.5.1 Comparison of Metals to LHAAP-Specific Background Concentrations in Soil

A comparison to site-specific background concentrations was used to determine whether detected chemicals were related to LHAAP operations. The LHAAP-specific background concentrations for soil were developed using data that represent background concentrations for soil (Shaw, 2004c).

Concentrations of metals in soil samples shown to have at least one value that exceeds human health and ecological screening values were compared with LHAAP-specific background concentrations according to statistical methods described in USEPA (2002a) guidance.

2.5.1.1 Statistical Distribution Tests

The Shapiro-Wilk test was performed using USEPA (2002a) guidance to determine the statistical distribution of the data and to ensure that the assumptions inherent in later statistical calculations are valid. The Shapiro-Wilk test was also used to determine the distribution type of background data (Shaw, 2004c). These distribution tests were made to determine whether the normal or lognormal distribution, or a nonparametric distribution, could be used in comparisons with background data.

The Shapiro-Wilk test calculates the statistic W to test the null hypothesis H_0 : that the population has a normal distribution versus the alternate hypothesis H_A : that the population does not have a normal distribution. When applied to the logarithms of data values, the lognormality of the distribution is tested.

Two indicators of background concentration were used for screening purposes, the 95 percent upper tolerance limit with 95 percent confidence (95%/95% UTL), and the 95 percent upper prediction limit (95% UPL). Both the 95%/95% UTL and the 95% UPL can be used to screen the upper tail of the background concentration. The 95%/95% UTL value represents the background concentration below which 95 per cent of the concentrations can be said to fall with 95 percent confidence. The 95% UPL value represents the concentration that will be above the next single measurement with 95 percent confidence. Both screening values were used in this

screening evaluation (**Table C-3**). Both screening values result in the same identification of COPCs with the exception of aluminum, which was identified only by the 95% UPL value.

The 95%/95% UTL concentration of each metal was described for soil previously (Shaw, 2004c). The 95% UPL of the background concentration (**Table C-3**) was calculated as follows. If the background data followed either the normal or lognormal distribution the 95% UPL was calculated according to the equation (USEPA, 1992b):

$$UPL_{0.95} = X + t_{n-1,0.95} \times S \times (1+1/n)^{1/2} \quad \text{Equation C-1}$$

where:

- $UPL_{0.95}$ = the 95% UPL
- X = mean background concentration
- $t_{n-1,0.95}$ = Student's t value for n-1 degrees of freedom and 95 percent confidence
- S = standard deviation of the mean
- n = number of samples

If the data were shown to be both normally and lognormally distributed, the distribution having the higher p value above 0.05 was used for the 95% UPL calculation. If the data were lognormally distributed, the 95% UPL value shown in **Table C-3** is the antilogarithm of the value calculated by Equation 1.

Nonparametric methods were used if the data do not follow either the normal or lognormal distribution. The 95% UPL concentration was determined by ranking the data from highest to lowest and calculating the 95th percentile rank according to the equation:

$$UPL_{0.95} = 95^{\text{th}} \text{ percentile} = 0.95(n+1) \quad \text{Equation C-2}$$

where:

- $UPL_{0.95}$ = concentration occupying the 95th percentile rank
- 95th percentile = the 95th percentile rank of the of the data set
- n = number of samples

This 95th percentile is the same as the 95% UPL according to the assumptions made in Equation C-1.

Comparison of MDC concentrations to RBSV values, to background screening concentrations represented by the 95%/95% UTL and 95% UPL values indicates that aluminum, antimony,

barium, cadmium, and mercury concentrations may exceed background levels (**Table C-3**) and, therefore, require direct statistical comparison to background data (USEPA, 2002a).

2.5.1.2 Statistical Comparisons

The 95%/95% UTL and the 95% UPL values were used for the initial screening of data (**Table C-3**). The statistical comparisons of LHAAP-48 samples with background were made according to USEPA (2002a) guidance.

All of the data sets in LHAAP-48 samples have either different distributions than the corresponding background data, or one distribution is nonparametric. Therefore, the data were compared using the Wilcoxon Rank Sum test (USEPA, 2002a), which tests for differences in median concentrations. All statistical inferences were made at the 95 percent confidence level. Tests were made using the Statistica[®] software package (StatSoft, 1997) at the 95 percent confidence level.

Box-and-whisker plots are a quick, robust graphical method recommended by the USEPA to visualize and compare two or more groups of data (USEPA, 1992b). These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75th percentile and the bottom of the box represents the 25th percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to the maximum and minimum values.

For each metal, box plots of site and background data are placed side by side to visually compare the distributions and qualitatively determine whether the data sets are similar. Examination of the box plots confirms the results of statistical calculations by either of the tests employed. The results of statistical comparisons for soil are shown in **Attachment 1** and are summarized in **Table C-4**.

Statistical comparisons of aluminum, antimony, barium, cadmium, and mercury concentrations with their respective background concentrations (**Table C-4**) indicate that these metals occur above background levels at LHAAP-48.

2.5.1.3 Geochemical Evaluations

Certain data sets (aluminum, antimony, barium, cadmium, and mercury) contain a high proportion of undetected concentrations or have other limitations, such as a skewed distribution or high variability. Because natural background concentrations are inherently variable and span a wide range of concentrations, statistical evaluations alone (especially those based on univariate statistics) sometimes lead to misleading and high background concentrations. Therefore, a geochemical evaluation of data was used as an independent check of statistical conclusions.

Geochemical evaluations examine ratios of concentrations of selected metals to confirm that the samples have the expected geochemical relationships. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples. When properly evaluated, geochemistry can provide mechanistic explanations for the observed variability in yet naturally occurring metal concentrations and provide an independent check on purely statistical evaluations.

The results of geochemical evaluations indicate that aluminum and mercury concentrations are consistent with background and that three antimony samples, three barium concentrations and seven cadmium concentrations may reflect contamination (**Attachment 2**).

The three antimony samples having anomalous geochemical ratios were from borings LH-S95-01, LH-S98-01, and LH-S101-01 (**Attachment 2**, Table 1), which are located near Sumps 095, 098, and 101, respectively (**Figure C-1**). The three barium samples were from boring LH-S95-01, near Sump 095, and borings LH-S123-01 and LH-Y-06, both near Sump 123 (**Figure C-1**). The seven cadmium samples were from four locations: LH-S101-01 near Sump 101, from two depths at LH-123-01 near Sump 123, from two depths at LH-S94-01 near Sump 094, and two depths at LH-WRS3-01 near WRS Sump 003 (**Attachment 2**, Table 1) (**Figure C-1**).

Of the three metals identified as COPCs (antimony, barium, and cadmium), barium is the metal most associated with flare and illuminator manufacturing at LHAAP-48 (main volume, Section 1.2). Because antimony compounds are used in pesticides and munitions, antimony could be related to LHAAP-48 operations. Cadmium is used in paint and other materials at industrial sites.

2.5.2 Organic Chemicals in Soil

Organic chemicals detected at concentrations above the screening criteria (**Table C-3**) are dioxins (as 2,3,7,8-tetrachloro-p-dibenzo dioxin, TCDD toxicity equivalent), and polycyclic aromatic hydrocarbons (PAHs) (benzo(a)anthracene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and phenanthrene), and vinyl chloride.

Dioxins are not associated with LHAAP explosives manufacturing operations or manufacture of illumination devices at LHAAP-48 operations (see main volume, Section 1.2). The dioxins were detected at concentrations near the risk-based MSSL screening value for residential land use (3.90E-06 milligrams per kilogram [mg/kg], **Table C-3**), which is based on a cancer risk of 1E-06. Thus, it is unlikely that a residential risk assessment based on the maximum 2,3,7,8-TCDD equivalent concentration (1.55E-05 mg/kg, **Table C-3**) would represent a cancer risk to a hypothetical resident above the 1E-06 to 1E-04 risk range considered acceptable by the USEPA (USEPA, 1994). However, dioxins were conservatively identified as COPCs in soil for hypothetical residential use of LHAAP-48.

The PAH compounds were identified infrequently and at low concentrations relative to the RBSV values (**Table C-3**). These compounds are not associated with LHAAP or LHAAP-48 operations, but could be associated with the asphalt paving of roads at LHAAP-48. Therefore, these four PAH compounds are not identified as COPCs in soil for hypothetical residential use of LHAAP-48.

Vinyl chloride is a degradation product of TCE, which may have been used as a solvent at LHAAP-48. Although the frequency of vinyl chloride detection is less than 5 percent (1 of 48 samples), the single detected concentration (4.97E-01 mg/kg) exceeds the Tier 2 Medium specific Concentration (MSC) specified for vinyl chloride in soil for residential land use scenarios (3.6E-02 mg/kg, TCEQ, 2004). Therefore, vinyl chloride is included in the risk assessment for LHAAP-48.

2.6 Summary

Table C-3 illustrates the COPC screening process for surface soil based on comparison to conservative screening values, comparison with background concentrations, and weight of evidence criteria. Antimony, barium, and cadmium were identified as COPCs in soil associated with Sumps 094, 095, 101, 123, and WRSump 003, and dioxins were associated with soil boring 48SB01, and vinyl chloride was associated with Sump 99.

3.0 Exposure Assessment

An exposure assessment estimates the type and magnitude of potential exposure of receptors to COPCs associated with a site according to the following steps (USEPA, 1989):

- Description of land and water uses
- Identification of potential receptors and exposure scenarios
- Identification of exposure pathways
- Estimation of exposure point concentrations for COPCs
- Estimation of COPC intake rates for each exposure pathway

3.1 Land and Water Uses

The LHAAP-48 was built in 1953 to 1955 for the production of igniters for pyrotechnic and illuminating devices and was active until approximately 1997. The site, known as the igniter production area has an area of approximately 16 acres and is located northwest of LHAAP-35C(53), the Static Test Area, at the intersections of Yoakum Drive and Starr Ranch Road (**Figure C-1**).

The perimeter of LHAAP-48 is a mixture of heavily wooded areas and grasslands. The topography slopes gently to the southeast, and surface runoff from the northern part of the site enters an unnamed rainwater drainage ditch to the south. Numerous manmade drainage ditches were observed in the production area (Plexus, 2005), but no standing water was observed in the drainage ways at that time. Runoff from the southern portion of LHAAP-48 eventually enters Central Creek to the southeast and on to Caddo Lake. Transport by surface water runoff and discharge of shallow groundwater to other surface water bodies is evaluated in a separate report (Shaw, 2006).

Silty clay at the surface is underlain by clay to approximately 7-8 ft bgs. Below several feet of clay is silty clay with some silty sand to clayey sand layers that make up the shallow unsaturated zone. The sand layers are not continuous across the site; another clay layer lies below the sand.

The hydraulic conductivity in the shallow zone was estimated at 3.8E-5 centimeters per second and the groundwater flow direction in the shallow zone is to the southeast toward Central Creek (Jacobs, 2002).

There are nine process sumps and three waste rack sumps located at the LHAAP-48 site which could have been affected by the production of igniters for pyrotechnic and illuminating devices (Jacobs, 2002, 2003). Surface features include asphalt roads and parking areas. Chemicals that

may be related to LHAAP processes have been identified (Plexus, 2005) and those potentially related to LHAAP-48 operations are expected to include:

- **Antimony:** compounds are used in munitions, pesticides, and pigments.
- **Barium:** used as an oxidizer in the manufacture of illumination devices as barium chromate and barium nitrate.
- **Chromium:** used in the manufacture of hand-held signals and illuminating projectiles (e.g., barium chromate, lead chromate) as a component of red phosphorous.
- **Lead:** present in many industrial components, such as batteries and paints. Used in process components (e.g., lead thiocyanate in fuse primers, lead styphnate in trip flares, and lead chromate in delay assemblies).
- **Mercury:** Metallic mercury was used in instrument gauges at the laboratories where quality of ingredients was tested.
- **Manganese:** used in the delay assembly of 155 mm illuminating projectiles.
- **Hexachlorobenzene:** used as an ingredient of pyrotechnics in aircraft signal production.
- **Other chemicals associated with the manufacture of munitions:** 2,4,6-trinitrotoluene (TNT), 2,4- and 2,6-dinitrotoluene, 1,2,5-trinitrobenzene, and HMX.
- **Chemicals associated with general industry:** cadmium associated with paint, zinc associated with galvanized iron, chlorinated hydrocarbons uses as solvents and their degradation products.

3.2 *Site Conceptual Model*

The exposure assessment for soil and groundwater at LHAAP-48 incorporates a conceptual site exposure model (CSEM) to provide the basis for identifying and evaluating the potential risks to a hypothetical resident and helps verify that exposures are not overlooked. The elements of a CSEM include:

- Source of affected media
- Chemical release mechanisms
- Chemical transport pathways
- Transport media
- Exposure media
- Receptors
- Exposure pathways

The CSEM developed for the LHAAP-48 residential land-use scenario assessment is the same model developed for the current trespasser and future on-site worker (Figure 3-2 of Jacobs, 2003) with the following exceptions:

- The resident will be exposed to COPCs in soil by incidental ingestion, inhalation of vapors and dust particles from soil and direct dermal contact.
- The resident will use shallow groundwater as a drinking water supply.
- Exposure of the resident to COPCs in fish is not assessed. Because the ephemeral unnamed creek at LHAAP-48 is in reality a rainwater ditch (**Section 3.1**), does not support a fish population, and a potential resident would have ready access to fish from Caddo Lake or one of the other watersheds, potential risk from ingestion of fish from the unnamed creek would represent the trespasser scenario evaluated in previous risk assessments (Jacobs, 2002, 2003). Therefore, the potential ingestion of fish from this ditch is not evaluated in this risk assessment.

The source-term concentration (STC) is the single concentration of a chemical that is representative of the environmental medium. Ideally, the STC should be the average concentration to which a receptor is exposed; i.e., the average calculated using all the samples taken from within a receptor's exposure area. Generally, the 95 percent upper confidence limit (95% UCL) on the arithmetic mean is estimated to account for uncertainty regarding adequacy of the sampling.

The 95% UCL was calculated using the bootstrapping technique for the residential risk assessment. Bootstrapping is a statistical technique where the given set of observations is re-sampled, with replacement (USEPA, 2002b). When repeated a large number of times, a relatively accurate estimation of the population variance can be determined, which allows for the development of confidence limits for the mean. Bootstrapping is considered a robust statistical method for calculating the UCL because it does not rely on assumptions on the distribution of the data set (USEPA, 2002b). Two thousand bootstrap replications were completed for each COPC. 95% UCLs were only developed for COPC, and only for chemicals with at least ten samples (TCEQ, 1998).

Information for COPCs in soil is summarized in **Table C-3**, which includes:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of laboratory reporting limit concentrations
- Type of statistical distribution of concentrations
- Arithmetic mean of site concentrations
- UCL on the arithmetic mean concentration

- Background screening concentration (the 95%, 95% upper tolerance limit (UTL, Shaw 2004c)
- The Texas RBSV concentration
- The 95% UPL concentration
- Identification of COPCs with the rationale for selection or rejection of a chemical as a COPC
- Source-term concentration used in the exposure assessment.

The 95% UCL or 95% UPL (**Table C-3**) could be used to estimate the most likely exposure (MLE) risk for hypothetical residents. Because the LHAAP-48 site area is larger than the expected area of a residential lot (1/8 acre, TCEQ, 1998), the maximum measure concentration of each COPC was selected as the STC for the risk assessment, and represents the reasonable maximum exposure (RME) scenario. This use of the maximum concentration includes the conservative assumption that the hypothetical resident could be exposed to the maximum concentration at any LHAAP-48 location. STC values for antimony, barium, cadmium, dioxins, and vinyl chloride were used in later exposure assessments for the hypothetical resident by the soil ingestion and dermal contact pathways. Use of the STC in the calculation of the airborne vapor and dust exposure concentration is described in **Section 3.5.2**.

3.3 Exposure Factors

This assessment is limited to the residential use of LHAAP-48. Assessments of maintenance workers and trespassers on LHAAP-48 were evaluated previously (Jacobs, 2003). If the LHAAP-48 resident visits other LHAAP sites or watersheds (Central Creek, Goose Prairie Creek, Harrison Bayou, or Saunder's Branch), those exposures are assumed to equal the trespasser scenario assessments reported for those sites (Jacobs, 2003).

The exposure factors used in the residential intake models are compiled in **Table C-5** (TCEQ, 1998; USEPA, 1989). Inhalation of vapor and dust emissions from soil and incidental ingestion and dermal contact pathways were assessed.

3.3.1 Identification of Exposure-Point Concentrations

The exposure-point concentrations of COPCs for direct exposure pathways for soil are the STCs estimated as described in **Section 3.2**. Exposure-point concentrations of COPCs for indirect inhalation exposure pathways that were estimated from soil STC are described in **Section 3.5.1**.

3.4 Identification of Exposure Models and Assumptions

The models used to quantify doses or intakes of the COPC by the identified exposure pathways were taken or modified from USEPA (1989) guidance and TCEQ (1998) guidance.

3.4.1 Ingestion Exposure to COPCs in Soil

The ingestion intake of carcinogenic COPCs in soil was estimated from the equation:

$$I_s = \frac{(C_s)(IR_{sadj})(EF)(CF)}{(AT)}$$

Equation C-3

where:

I_s	=	ingestion intake of COPC in soil (mg/kg-day, calculated)
C_s	=	concentration of COPC in soil (mg/kg)
IR_{sadj}	=	age-adjusted ingestion rate of soil (mg-year/kg-day)
EF	=	exposure frequency (days/year)
CF	=	conversion factor (1E-6 kg/mg)
AT_c	=	averaging time for carcinogens (days; = 70 years × 365 days/year).

The ingestion intake of noncarcinogenic COPCs in soil were calculated according to the equation:

$$I_s = \frac{(C_s)(IR_{sadj})(EF)(CF)}{(AT)}$$

Equation C-4

where:

I_s	=	ingestion intake of COPC in soil (mg/kg-day, calculated)
C_s	=	concentration of COPC in soil (mg/kg)
IR_{sadj}	=	age-adjusted ingestion rate of soil (mg-year/kg-day)
EF	=	exposure frequency (days/year)
CF	=	conversion factor (1E-6 kg/mg)
AT	=	averaging time for exposure to noncarcinogen (days; = 30 years × 365 days/year).

3.4.2 Inhalation Exposures to COPCs in Soil

The inhalation intake of carcinogenic COPCs in airborne vapor and dust suspended from soil is estimated from the equation:

$$C_a = \frac{(C_s)(CF)(EF)(ED)(1/VF + 1/PEF)}{(AT_c)} \quad \text{Equation C-5}$$

where:

C_a	=	concentration of COPC in airborne dust (micrograms per cubic meter [$\mu\text{g}/\text{m}^3$])
C_s	=	concentration of COPC in soil (mg/kg)
CF	=	conversion factor (1E3 $\mu\text{g}/\text{mg}$)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)
VF	=	volatilization factor (m^3/kg), chemical specific value calculated as described below
PEF	=	particulate emission factor ($4.63 \times 10^9 \text{ m}^3/\text{kg}$, TCEQ, 1998)
ATc	=	averaging time for carcinogens (days; = 70 years x 365 days/year).

The inhalation intake of airborne noncarcinogenic COPCs was calculated according to the equation:

$$C_a = \frac{(C_s)(EF)(ED)(1/VF + 1/PEF)}{(AT)} \quad \text{Equation C-6}$$

where:

C_a	=	concentration of COPC in airborne dust (mg/m^3)
C_s	=	concentration of COPC in soil (mg/kg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)
AT	=	averaging time for exposure to noncarcinogens (days)
PEF	=	particulate emission factor ($4.63 \times 10^9 \text{ m}^3/\text{kg}$, TCEQ, 1998).

Because metals are not volatile, in inhalation exposure assessments for antimony, barium, and cadmium are based on the PEF only.

3.4.2.1 Volatilization Factor

The volatilization factor for the dioxin vapor inhalation assessment was calculated using the following equation (TCEQ, 1998):

$$VF = \frac{(LS \cdot V \cdot DH)}{A} \times \frac{[3.14 \cdot a \cdot T]^{1/2}}{2 \cdot D_{ei} \cdot E \cdot K_{as}} \times 10^{-3} \text{ kg / g}$$

Equation C-7

and:

$$\alpha = \frac{D_{ei} \cdot E}{E + (p_s \cdot I - E) / K_{as}}$$

Equation C-8

$$K_{as} = (H / K_d) 41$$

where:

- LS = the length of contaminated area (925 feet, 320 meters [m], **Figure C-1**)
- V = wind speed in mixing zone (2.25 m/second [sec], TCEQ, 1998)
- DH = diffusion height (2 m, TCEQ, 1998)
- A = area of contamination, 578, 125 ft² (6.45E+8 centimeter square [cm²])
- T = exposure interval (sec, TCEQ, 1998)
- D_{ei} = effective diffusivity (cm²/s); equal to [(D_i)(E^{0.33})], where D_i is the chemical specific molecular diffusivity in air (cm²/s)
- E = default soil porosity (unitless, 0.35, TCEQ, 1998)
- p_s = soil or particulate density (2.65 grams [g]/cubic centimeters [cm³], TCEQ, 1998)
- K_{as} = soil to air partition coefficient (g soil/cm³ air)
- H = chemical specific Henry's Law constant (atm-m³/mol)
- K_d = chemical specific soil to water partition coefficient (cm³/g, K_d = K_{oc} × f_{oc})
- K_{oc} = organic carbon partition coefficient (cm³/g)
- f_{oc} = fraction soil organic carbon content, (0.02, TCEQ, 1998).

3.4.3 Dermal Exposures to COPCs in Soil

Unlike the methods for estimating ingested intake of COPC, which quantify an administered dose, dermal dose is estimated as the dose that crosses the skin and is absorbed. For this reason, dermal toxicity values are also based on absorbed dose.

The absorbed dose of carcinogenic COPCs through contact with soil was estimated from the equation:

$$DAD = \frac{(C_s)(MCF)(DFadj)(ABSd)(EF)}{(ATc)} \quad \text{Equation C-9}$$

where:

DAD	=	average dermally absorbed dose of COPC from soil exposure (mg/kg-day, calculated)
C _s	=	concentration of COPC in soil (mg/kg)
MCF	=	mass conversion factor (1E-6 kg/mg)
ABSd	=	dermal absorption fraction of chemical (unitless)
DFadj	=	age-adjusted dermal absorption factor (mg-yr/kg-day)
EF	=	exposure frequency (days/year)
ATc	=	averaging time for carcinogens (days; = 70 years x 365 days/year).

Dermal absorption factor (ABSd) values are provided in TCEQ (1998) guidance. The dermal absorbed doses of noncarcinogenic COPCs in soil (except cadmium) are usually calculated separately for children and adults according to the equation:

$$DAD = \frac{(C_s)(MCF)(ED)(EF)(SA)(AF)(ABSd)}{(BW)(AT)} \quad \text{Equation C-10}$$

where:

DAD	=	average dermally absorbed dose of COPC to the child or the adult from exposure to soil (mg/kg-day, calculated)
MCF	=	conversion factor (1E-6 kg/mg)
ED	=	exposure duration; (6 years for child, 24 years for adult)

EF	=	exposure frequency (days/year)
SA	=	surface area of exposed skin (2200 cm ² for child, 2500 cm ² for adult)
AF	=	adherence factor of soil to skin; (0.2 mg/cm ² -day for both child and adult receptors)
ABSd	=	dermal absorption fraction of chemical (unitless value same for both child and adult receptors)
BW	=	body weight: (15 kg for child, 70 kg for adult)
AT	=	averaging time for noncarcinogens (days; = 6 years x 365 days/year for child, 24 years x 365 days/year for adult).

Because the surface area of skin exposed for the adult receptor is slightly higher than that of the child, the dermal DAD calculated for the adult is slightly higher than the child's DAD by a factor of 2500 cm² / 2200 cm², or approximately 14%. However, this slightly greater adult exposure is more than offset by the lower body weight of the child, such that the DAD calculated for the child exceeds that of the adult by a factor of 70 kg / 15 kg, or approximately 460%. Therefore, the exposures calculated for the child are protective of the adult.

The dermal absorbed dose of cadmium was calculated for both children and adults according to the equation (TCEQ, 1998):

$$DAD = \frac{(C_s)(MCF)(EF)(DFadj)(ABSd)}{(AT.AgeAdj)}$$

Equation C-11

where:

DAD	=	average dermally absorbed dose of cadmium to the child or the adult from exposure to soil (mg/kg-day, calculated)
MCF	=	conversion factor (1E-6 kg/mg)
DFadj	=	age-adjusted dermal factor (mg-yr/kg-day)
ABSd	=	dermal absorption fraction of chemical (unitless value same for both child and adult receptors)
EF	=	exposure frequency (days/year)
AT.AgeAdj	=	age-adjusted averaging time for dermal exposure to cadmium (days; = 30 years x 365 days/year).

4.0 Toxicity Assessment

The toxicity assessment identifies the cancer and noncancer effects that may arise from exposure of humans to the COPC and provides an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects. The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described in the following sections.

4.1 Carcinogenic Effects

The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (USEPA, 1989). The qualitative aspect is a weight-of-evidence evaluation of the likelihood that a chemical might induce cancer in humans. The USEPA recognizes six weight-of-evidence group classifications for carcinogenicity:

- Group A - Human Carcinogen: human data are sufficient to identify the chemical as a human carcinogen
- Group B1 - Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed
- Group B2 - Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association
- Group C - Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation
- Group D - Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate
- Group E - Evidence of Noncarcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer

The toxicity value for carcinogenicity, the cancer slope factor (SF), is an estimate of potency. Potency estimates are developed only for chemicals in Groups A, B1, B2 and C, and only if the data are sufficient. The potency estimates are statistically derived from the dose-response curve from the best human or animal study or studies of the chemical. The cancer risk factor for inhaled carcinogens is the unit risk factor (URF) and also represents an estimate of cancer potency when applied to the airborne carcinogen concentration to which the person is exposed.

The SF is usually expressed as "extra risk" per unit of intake or exposure; that is, the additional risk above the incidence in an unexposed population. The SF is expressed as risk per mg/kg-day.

The URF is expressed as risk per $\mu\text{g}/\text{m}^3$. In order to be appropriately conservative, the SF (or URF) is usually the 95 percent upper bound on the slope of the dose-response curve extrapolated from high (experimental) doses to the low-dose range expected in environmental exposure scenarios. USEPA (1989) assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk.

4.2 *Noncarcinogenic Effects*

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (USEPA, 1989) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical; these may differ depending on the duration (e.g., acute or chronic) or route (e.g., oral or inhalation) of exposure
- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased)
- Estimation of the threshold dose for the critical effect for each duration of exposure
- Development of an uncertainty factor; i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of the critical effect, slope of the dose-response curve, and deficiencies in the data base in regard to developing a reference dose (RfD) for human exposure.
- Identification of the target organ for the critical effect for each route of exposure.

This information is used to derive the reference dose, RfD, which is an exposure route- and duration-specific toxicity value expressed as $\text{mg}/\text{kg}\cdot\text{day}$. The RfD is considered to be the dose for humans, with uncertainty of an order of magnitude or greater, at which adverse effects are not expected to occur. The noncancer hazard for inhaled noncarcinogens is the reference concentration (RfC) and also represents an estimate of toxicity when applied to the airborne concentration to which the person is exposed. The RfC is expressed in units of mg/m^3 and also represents an estimate of noncancer hazard when applied to the airborne concentration to which the person is exposed.

Dermal SFs and RfDs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (ABS_{GI}), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral

SF by the ABS_{GI} . The oral SF is divided, rather than multiplied, by the ABS_{GI} because SFs are expressed as reciprocal doses.

Toxicity values were chosen using the following hierarchy:

- USEPA's on-line integrated risk information system (IRIS) database (USEPA, 2006) containing toxicity values that have undergone the most rigorous Agency review
- toxicity values provided in TCEQ (1998) guidance or in 30TAC§350 guidance as updated through March 2006.
- The ABS_{GI} values used to derive dermal RfDs and SFs from the corresponding oral toxicity values were obtained from TCEQ guidance (TCEQ, 1998).

Toxicity values for the 2,3,7,8-TCDD TEQ dioxin surrogate were evaluated using the following documents:

- USEPA's on-line integrated risk information system (IRIS) database (USEPA, 2006) containing toxicity values that have undergone the most rigorous Agency review
- Toxicity values provided in TCEQ (1998) guidance or in 30TAC§350 guidance as updated through March 2006.
- *Human Health Medium-Specific Screening Levels*, November 2004, (USEPA, 2004) accessed online in January 2006.
- *Health Effects Assessment Summary Tables (HEAST)*, (HEAST, 1997), adopted in the USEPA (2004) document.
- The ABS_{GI} values used to derive dermal RfDs and SFs from the corresponding oral toxicity values were obtained from TCEQ guidance (TCEQ, 1998, 2004).

Toxicity factors used in the evaluation of cancer risk and noncancer hazard are shown in **Table C-6**.

5.0 Risk Characterization

Risk characterization is the combination of the results of the exposure assessment and toxicity assessment to yield a quantitative expression of cancer risk or noncancer hazard for the exposed receptors. This quantitative expression is the probability of developing cancer, or a non-probabilistic comparison of estimated dose with a reference dose for noncancer effects. Quantitative estimates are developed for individual chemicals, exposure pathways, and exposure media for each receptor. The risk characterization follows USEPA (1989) methodology as modified by more recent information and guidance. The USEPA methods are, appropriately, designed to be health-protective and tend to overestimate, rather than underestimate, risk.

5.1 Carcinogenic Effects Of Chemicals

The risk from exposure to chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime, and is called the incremental lifetime cancer risk (ILCR). In the low-dose range, which would be expected for most environmental exposures, cancer risk from exposure by ingestion and dermal exposures is estimated from the following linear equation (USEPA, 1989):

$$ILCR = (CDI)(SF) \quad \text{Equation C-12}$$

where:

- ILCR = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence (calculated)
- CDI = chronic daily intake, averaged over 70 years (mg/kg-day); I_s (see Equation C-3) or DAD (see Equation C-9),
- SF = cancer slope factor (per mg/kg-day).

The cancer risk from exposure to carcinogens by the inhalation pathway is estimated from the following linear equation (TCEQ, 1998):

$$ILCR = (C_a)(URF) \quad \text{Equation C-13}$$

where:

- ILCR = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence (calculated)

C_a = concentration of carcinogenic COPC in airborne dust ($\mu\text{g}/\text{m}^3$) (see Equation C-5)

URF = cancer slope factor (per $\mu\text{g}/\text{m}^3$).

As a matter of policy, USEPA (1989) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemical's mechanisms of toxicity or sites (organs of the body) of action. Cancer risk arising from simultaneous exposure by a given pathway to multiple chemicals is estimated from the following equation:

$$Risk_p = ILCR_{(chem\ 1)} + ILCR_{(chem\ 2)} + ILCR_{(chem\ i)} \quad \text{Equation C-14}$$

where:

$Risk_p$ = total pathway risk of cancer incidence (calculated)

$ILCR(chem_i)$ = individual chemical cancer risk

Cancer risk for a given receptor across pathways and across media is summed in the same manner.

5.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects are evaluated by comparing an exposure level or intake with an RfD. The HQ from exposure by ingestion and dermal exposures, defined as the ratio of intake to RfD, is estimated as (USEPA, 1989):

$$HQ = I / RfD \quad \text{Equation C-15}$$

where:

HQ = hazard quotient (unitless, calculated)

I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day); I_s (see Equation C-4) or DAD (see Equation C-10, or C-11 for dermal exposure to cadmium)

RfD = reference dose (mg/kg-day)

Chemical noncancer hazards are evaluated using chronic RfD values. This approach is different from the probabilistic approach used to evaluate cancer risks. An HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than

the RfD. An HQ of unity indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects.

The noncancer hazard from exposure by the inhalation pathway is estimated from the following linear equation (TCEQ, 1998):

$$HQ = (C_a) / (RfC) \quad \text{Equation C-16}$$

where:

HQ	=	hazard quotient (unitless, calculated)
C _a	=	concentration of noncarcinogenic COPC in airborne dust (mg/m ³) (see Equation C-6)
RfC	=	reference concentration (mg/m ³).

In the case of simultaneous exposure of a receptor to several chemicals, an HI is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \dots HQ_i \quad \text{Equation C-17}$$

where:

HI	=	hazard index (unitless, calculated)
HQ _i	=	hazard quotient for the i th toxicant.

5.3 Risks Associated With Exposure to Soil

Antimony, barium, cadmium, dioxins, and vinyl chloride were identified as COPCs in soil (**Table C-3**). The estimated cancer risk and noncancer hazard from potential exposure by the ingestion pathway are shown in **Tables C-7a** and **C-7b**. The cancer risks and noncancer hazards from potential exposures by the inhalation and dermal exposure pathways are shown in **Tables C-8a** and **C-8b**, and **Tables C-9a** and **C-9b**, respectively. Total cancer risk and noncancer hazard estimated for exposures of the potential resident to all COPCs by all pathways are shown in **Tables C-10a** and **C-10b**.

The total cancer risk (6E-05, **Table C-10a**) is well below the acceptable range of (1E-06 to 1E-04) (USEPA, 1994). The noncancer hazard (Total HI, 4E-01, **Table C-10b**) is less than 1 and is, therefore, below acceptable limits (USEPA, 1994). Therefore, chemicals are not of concern for exposures of potential residents to soil at LHAAP-48.

6.0 *Uncertainty Analysis*

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements, e.g., analytical accuracy and precision associated with contaminant concentrations. The results of this risk assessment reflect the accumulated variances of the individual measured values.

A different kind of uncertainty stems from data gaps, i.e., additional information needed to complete the database for the assessment, uncertainties associated with exposure parameters assumed for children and adults (**Table C-5**), toxicity factors used in the characterization of risk (**Table C-6**), and assumptions regarding additivity of risk and hazard estimates (**Sections 5.1** and **5.2**). The methodology accounts for these uncertainties by using various conservative assumptions that result in overestimations of risks. This risk assessment incorporates all of these uncertainties, which are discussed in detail in USEPA (1989) guidance and the previous risk assessment (Jacobs, 2003).

The assumption that potential residents would be exposed to the maximum concentration of all COPCs represents a conservative assumption leading to an expected over-estimation of risk at LHAAP-48.

7.0 References

Jacobs, 2002, *Final Remedial Investigation Report, Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60,67, Goose Prairie Creek, Volumes 1 and 2: Report*, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee, April.

Jacobs, 2003, *Draft Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60,67, Goose Prairie Creek, Saunder's Branch, and Caddo Lake, Volume 1, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee*, June.

Plexus Scientific, Inc. (Plexus), 2005, *Final Environmental Site Assessment Phase I and II Report, Production Areas, Longhorn Army Ammunition Plant, Karnack, Texas*, February.

Shaw Environmental, Inc. (Shaw), 2004a, *Final Work Plan Groundwater Data Gaps Investigation Groups 2 and 4, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, February.

Shaw, 2004b, *Final Installation-Wide Background Study Work Plan, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, January.

Shaw, 2004c, *Final Background Soil Study Report, Longhorn Army Ammunition Plant, Karnack Texas*, Houston, Texas, July.

Shaw, 2005, *Draft Final Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas*, Houston, Texas, May.

Shaw, 2006, *Final Modeling Report, Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army ammunition Plant, Karnack, Texas*, September.

StatSoft, Inc. 1997. *STATISTICA for Windows Version 5.1*, Tulsa, OK, <<http://www.statsoft.com>> (February 2004).

Texas Commission on Environmental Quality (TCEQ), 1998, Interoffice Memorandum from Ronald R. Pedde to Remediation Division Staff regarding implementation of the existing risk reduction rules (a.k.a. TNRCC Consistency Memorandum), July.

TCEQ, 2001. Interoffice Memorandum from Joseph T. Haney, Jr., (TCEQ) to Camarie Perry, Office of Permitting, Remediation & Registration, *Evaluation of the Potential Health Impacts of Exposure to Iron, Calcium, Magnesium, Potassium, sodium, and Phosphorus through Soil Ingestion*, October.

TCEQ, 2003, Interoffice Memorandum, *Compounds for which Calculation of a Human Health MSC is Not Required*, October, available online <http://www.tnrcc.state.tx.us/permitting/rrr.htm>

TCEQ, 2004, Texas Risk Reduction Rules (30TAC§335) as updated through March 2006.

U.S. Environmental Protection Agency (USEPA), 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-0202, March.

USEPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, EPA/540/1-89/002, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, September.

USEPA, 1992a, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Third Edition (September, 1992), with Updates I-III*.

USEPA, 1992b, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*, EPA/530/R-93/003, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, July.

USEPA, 1992c, *Guidance for Data Usability in Risk Assessment (Part A)*, EPA Publication 9285.7-09A, PB92-973356, Office of Emergency and Remedial Response, April.

USEPA, 1994, *National Oil and Hazardous Substances Pollution Contingency Plan*, 40 Code of Federal Regulations Part 300, 59 Federal Register 47384, October 10.

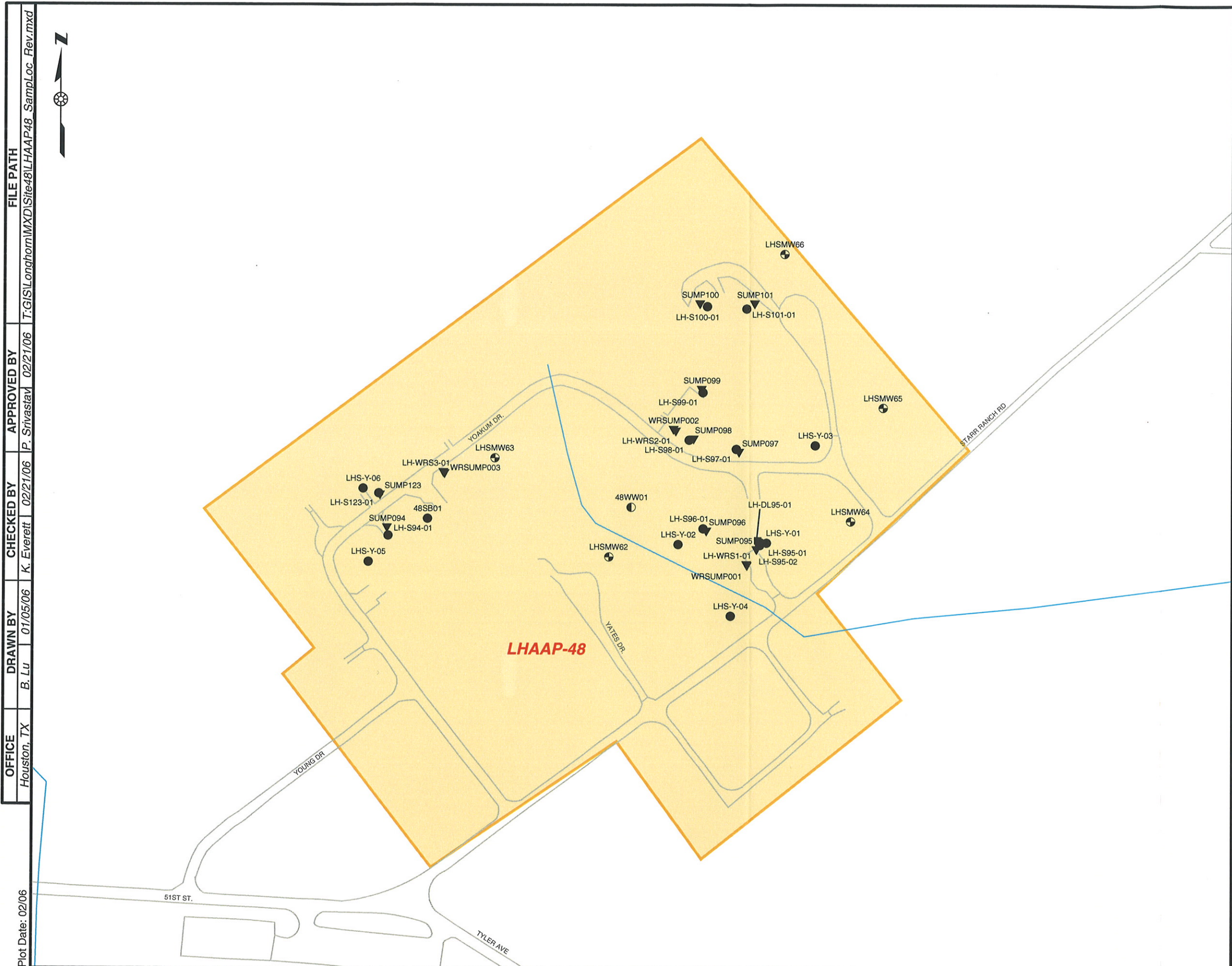
USEPA, 2002a, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, EPA 540-R-01-003, OSWER 9285.7-41, Office of Environmental and Remedial Response, September.









USEPA, 2002b, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, OSWER 9285.6-10, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

USEPA, 2006, Integrated Risk Information System (IRIS), U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. accessed at <<http://www.epa.gov/iris>, January 2006.

Van den Berg, M., Birnbaum, L., Bosveld, A.T.C., Brunstrom, B., Cook, P., Feeley, M., Giesy, J.P., Hanberg, A., Hasegawa, R., Kennedy, S.W., Kubiak, T., Larsen, J.C., van Leeuwen, F.X.R., Liem, A.K.D., Nolt, C., Peterson, R.E., Poellinger, L., Safe, S., Schrenk, D., Tillitt, D., Tysklind, M., Younes, M., Waern, F. and Zacharewski, T., 1998, *Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife*, Environmental Health Perspectives 106(12):775-792.

Figures



-  Shallow Monitoring Well
-  Intermediate Monitoring Well
-  Surface Soil
-  Soil boring
-  Sump
-  Stream
-  Road
-  Site



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

FIGURE C-1

LHAAP-48 SAMPLE LOCATION MAP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Tables

Table C-1
Soil Samples
LHAAP-48
Longhorn Army Ammunition Plant
Karnack, Texas

Location	Sample Number	Purpose	Type	Sample Date	Depth (ft)	Analyses
Soil ^a						
48SB01	48SB01(0-0.5)	REG	SST	28-Jul-98	0 - 0.5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
48SB01	48SB01(1-3)	REG	SS	28-Jul-98	1 - 3	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
48SB01	48SB01(1-3)QC	FD	SS	28-Jul-98	1 - 3	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
48SB01	48SB01(3-5)	REG	DS	28-Jul-98	3 - 5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
SUMP094	SUMP094(0-0.5)	REG	SS	28-Jul-98	0 - 0.5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
SUMP094	SUMP094(3-5)	REG	DS	28-Jul-98	3 - 5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
SUMP095	SUMP095(0-0.5)	REG	SS	4-Aug-98	0 - 0.5	Dioxins, Exp, Metals, SVOC, VOC
SUMP095	SUMP095(3-5)	REG	DS	4-Aug-98	3 - 5	Dioxins, Exp, Metals, SVOC, VOC
SUMP098	SUMP098(0-0.5)	REG	SS	4-Aug-98	0 - 0.5	Dioxins, Exp ^b , Metals, SVOC, VOC
SUMP098	SUMP098(3-5)	REG	DS	4-Aug-98	3 - 5	Dioxins, Exp ^b , Metals, SVOC, VOC
SUMP100	SUMP100(0-0.5)	REG	SS	7-Aug-98	0 - 0.5	Dioxins, Exp ^b , Metals, SVOC, VOC
SUMP100	SUMP100(3-5)	REG	DS	7-Aug-98	3 - 5	Dioxins, Exp ^b , Metals, SVOC, VOC
WRSUMP001	WRSUMP001(0-5)	REG	SS	6-Aug-98	0 - 0.5	Dioxins, Exp, Metals, SVOC, VOC
WRSUMP001	WRSUMP001(3-5)	REG	DS	6-Aug-98	3 - 5	Dioxins, Exp, Metals, SVOC, VOC
WRSUMP003	WRSUMP003(0-0.5)	REG	SS	6-Aug-98	0 - 0.5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
WRSUMP003	WRSUMP003(3-5)	REG	DS	6-Aug-98	3 - 5	Dioxins, Exp, Metals, Pest, PCB, SVOC, VOC
HOSB16	HOSB16(3-5)	REG	DS	6-Dec-00	3 - 5	TPH
HOSB16	HOSB16(3-5)QC	FD	DS	6-Dec-00	3 - 5	TPH
HOSB16	HOSB16(0-0.5)	REG	SST	6-Dec-00	0 - 0.5	TPH
HOSB16	HOSB16(8-10)	REG	DS	6-Dec-00	8 - 10	TPH
LH-DL95-01	LH-DL95-01	REG	SS	26-Jun-93	2 - 2.5	Exp ^b , Metals, SVOC, VOC
LH-S100-01	LH-S100-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S100-01	LH-S100-01 QC	FD	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S100-01	LH-S100-01_2	REG	SS	26-Jun-93	1.5 - 3	Exp ^b , Metals, SVOC, VOC
LH-S101-01	LH-S101-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S101-01	LH-S101-01_2	REG	DS	26-Jun-93	3.8 - 4.2	Exp ^b , Metals, SVOC, VOC
LH-S123-01	LH-S123-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S123-01	LH-S123-01_2	REG	DS	26-Jun-93	11 - 12.5	Exp ^b , Metals, SVOC, VOC
LH-S94-01	LH-S94-01_1	REG	SS	20-Aug-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S94-01	LH-S94-01_2	REG	DS	20-Aug-93	2.9 - 3.5	Exp ^b , Metals, SVOC, VOC
LH-S95-01	LH-S95-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S95-01	LH-S95-01 QC	FD	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S95-01	LH-S95-01_2	REG	DS	26-Jun-93	5.5 - 6.2	Exp ^b , Metals, SVOC, VOC
LH-S95-01	LH-S95-01_3	REG	DS	26-Jun-93	11.3 - 12	Exp ^b , Metals, SVOC, VOC
LH-S95-02	LH-S95-02_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S95-02	LH-S95-02_2	REG	DS	26-Jun-93	4 - 4.5	Exp ^b , Metals, SVOC, VOC
LH-S95-02	LH-S95-02_3	REG	DS	26-Jun-93	5.5 - 6	Exp ^b , Metals, SVOC, VOC
LH-S96-01	LH-S96-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S96-01	LH-S96-01_2	REG	SS	26-Jun-93	2 - 2.8	Exp ^b , Metals, SVOC, VOC
LH-S96-01	LH-S96-01_3	REG	DS	26-Jun-93	11 - 12.5	Exp ^b , Metals, SVOC, VOC
LH-S97-01	LH-S97-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S97-01	LH-S97-01_2	REG	DS	26-Jun-93	3.9 - 4.7	Exp ^b , Metals, SVOC, VOC
LH-S97-01	LH-S97-01_3	REG	DS	26-Jun-93	11 - 11.7	Exp ^b , Metals, SVOC, VOC
LH-S98-01	LH-S98-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S98-01	LH-S98-01_2	REG	SS	26-Jun-93	1.5 - 3	Exp ^b , Metals, SVOC, VOC
LH-S99-01	LH-S99-01_1	REG	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S99-01	LH-S99-01 QC	FD	SS	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-S99-01	LH-S99-01_2	REG	SS	26-Jun-93	2 - 2.8	Exp ^b , Metals, SVOC, VOC
LH-S99-01	LH-S99-01_3	REG	DS	26-Jun-93	12 - 12.8	Exp ^b , Metals, SVOC, VOC

Table C-1
Soil Samples
LHAAP-48
Longhorn Army Ammunition Plant
Karnack, Texas

Location	Sample Number	Purpose	Type	Sample Date	Depth (ft)	Analyses
LHSMW62	LHS-MW62	REG	SST	5-Oct-94	0 - 0.5	Exp, Metals, SVOC, VOC
LHSMW63	LHS-MW63	REG	SST	5-Oct-94	0 - 0.5	Exp, Metals, SVOC, VOC
LHSMW64	LHS-MW64	REG	SST	5-Oct-94	0 - 0.5	Exp, Metals, SVOC, VOC
LHSMW65	LHS-MW65	REG	SST	5-Oct-94	0 - 0.5	Exp, Metals, SVOC, VOC
LHSMW66	LHS-MW66	REG	SST	5-Oct-94	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-01	LHS-Y-01	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-01	LHS-Y-01QC	FD	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-02	LHS-Y-02	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-03	LHS-Y-03	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-04	LHS-Y-04	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-05	LHS-Y-05	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LHS-Y-06	LHS-Y-06	REG	SLDG	11-Jan-95	0 - 0.5	Exp, Metals, SVOC, VOC
LH-WRS1-01	LH-WRS1-01_1	REG	SLDG	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-WRS1-01	LH-WRS1-01 QC	FD	SLDG	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-WRS1-01	LH-WRS1-01_2	REG	SLDG	26-Jun-93	3.5 - 5	Exp ^b , Metals, SVOC, VOC
LH-WRS1-01	LH-WRS1-01_3	REG	SLDG	26-Jun-93	11 - 12.5	Exp ^b , Metals, SVOC, VOC
LH-WRS2-01	LH-WRS2-01_1	REG	SLDG	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-WRS2-01	LH-WRS2-01_2	REG	SLDG	26-Jun-93	3 - 3.7	Exp ^b , Metals, SVOC, VOC
LH-WRS3-01	LH-WRS3-01_1	REG	SLDG	26-Jun-93	0.5 - 1.5	Exp ^b , Metals, SVOC, VOC
LH-WRS3-01	LH-WRS3-01_2	REG	SLDG	26-Jun-93	3.5 - 4.3	Exp ^b , Metals, SVOC, VOC
LH-WRS3-01	LH-WRS3-01_3	REG	SLDG	26-Jun-93	10.5 - 10.9	Exp ^b , Metals, SVOC, VOC

^a Surface soil is defined as 0 to 15 feet below ground surface.

^b Explosive analysis includes only 2,4- and 2,6-dinitrotoluene.

DS = Subsurface soil sample

Exp = Explosives

FD = Field duplicate; the field duplicate was averaged with the regular sample to produce one result for the same sample location and depth.

ft = feet below ground surface

PCB = Polychlorinated biphenyls

Pest = Organochlorine pesticides

REG = Regular environmental sample

SLDG = Sludge sample

SO = Soil sample

SS = Surface soil sample

SST = Surface soil-top layer sample

SVOC = Semivolatile organic compound

TPH = Total petroleum hydrocarbon

VOC = Volatile organic compound

Table C-2
2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP- 48

Location:		48SB01		48SB01		48SB01	
Sample Number:		48SB01(0-0.5)		48SB01(1-3)		48SB01(3-5)	
Date Sampled:		7/28/1998		7/28/1998		7/28/1998	
Depth (ft.):		0-0.50		1-3		3-5	
DIOXIN AND FURAN CONGENERS	TEF	Concentration (ng/kg)	TEQ	Concentration (ng/kg)	TEQ	Concentration (ng/kg)	TEQ
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	1	0.393	3.93E-01	0.065	6.50E-02	0.0765	7.65E-02
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	1	0.815	8.15E-01	0.08	8.00E-02	0.0955	9.55E-02
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.1	5.042	5.04E-01	0.405	4.05E-02	0.0925	9.25E-03
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.1	13.723	1.37E+00	1.03	1.03E-01	0.0855	8.55E-03
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.1	10.279	1.03E+00	0.749	7.49E-02	0.082	8.20E-03
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	0.01	321.192	3.21E+00	36.438	3.64E-01	3.497	3.50E-02
OCTACHLORODIBENZO-p-DIOXIN	0.0001	2578.666	2.58E-01	2440.99	2.44E-01	137.899	1.38E-02
2,3,7,8-TETRACHLORODIBENZOFURAN ^a	0.1	0.144	1.44E-02	0.204	2.04E-02	0.142	1.42E-02
1,2,3,7,8-PENTACHLORODIBENZOFURAN	0.05	10.457	5.23E-01	0.46	2.30E-02	0.0695	3.48E-03
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.5	0.556	2.78E-01	0.05	2.50E-02	0.0705	3.53E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	0.1	6.398	6.40E-01	0.508	5.08E-02	0.046	4.60E-03
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	0.1	4.603	4.60E-01	0.278	2.78E-02	0.044	4.40E-03
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.1	3.765	3.77E-01	0.059	5.90E-03	0.05	5.00E-03
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	0.01	59.918	5.99E-01	4.061	4.06E-02	0.362	3.62E-03
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	0.01	1.61	1.61E-02	0.94	9.40E-03	0.076	7.60E-04
OCTACHLORODIBENZOFURAN	0.0001	93.385	9.34E-03	7.522	7.52E-04	0.108	1.08E-05
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^b =			1.05E-05		1.18E-06		3.18E-07
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment is 1.55E-05 mg/kg, the maximum value.							

Table C-2
2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP- 48

Location:	SUMP094		SUMP094		SUMP095	
Sample Number:	SUMP094(0-0.5)		SUMP094(3-5)		SUMP095(0-0.5)	
Date Sampled:	8/7/1998		8/7/1998		8/4/1998	
Depth (ft.):	0-0.50		3-5		0-0.50	
DIOXIN AND FURAN CONGENERS	Concentration	TEQ	Concentration	TEQ	Concentration	TEQ
	(ng/kg)		(ng/kg)		(ng/kg)	
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	1.159	1.16E+00	0.211	2.11E-01	0.224	2.24E-01
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	1.669	1.67E+00	0.179	1.79E-01	0.229	2.29E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	2.333	2.33E-01	0.215	2.15E-02	0.7125	7.13E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	15.399	1.54E+00	0.12	1.20E-02	14.63	1.46E+00
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	1.548	1.55E-01	0.143	1.43E-02	10.442	1.04E+00
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	504.751	5.05E+00	0.666	6.66E-03	366.06	3.66E+00
OCTACHLORODIBENZO-p-DIOXIN	5370.28	5.37E-01	20.392	2.04E-03	8678.074	8.68E-01
2,3,7,8-TETRACHLORODIBENZOFURAN ^a	1.621	1.62E-01	2.293	2.29E-01	1.935	1.94E-01
1,2,3,7,8-PENTACHLORODIBENZOFURAN	11.341	5.67E-01	0.12	6.00E-03	0.206	1.03E-02
2,3,4,7,8-PENTACHLORODIBENZOFURAN	2.07	1.04E+00	0.126	6.30E-02	0.212	1.06E-01
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	22.923	2.29E+00	0.112	1.12E-02	14.042	1.40E+00
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	2.027	2.03E-01	0.0745	7.45E-03	1.8255	1.83E-01
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	2.969	2.97E-01	0.109	1.09E-02	2.979	2.98E-01
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	55.647	5.56E-01	0.487	4.87E-03	91.159	9.12E-01
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	4.2	4.20E-02	0.117	1.17E-03	10.178	1.02E-01
OCTACHLORODIBENZOFURAN	144.758	1.45E-02	0.0975	9.75E-06	607.443	6.07E-02
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^b =		1.55E-05		7.80E-07		1.08E-05
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment is 1.55E-05 mg/kg, the maximum value.						

Table C-2
2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP- 48

Location:	SUMP095		SUMP098		SUMP098	
Sample Number:	SUMP095(3-5)		SUMP098(0-0.5)		SUMP098(3-5)	
Date Sampled:	8/4/1998		8/4/1998		8/4/1998	
Depth (ft.):	3-5		0-0.50		3-5	
	Concentration		Concentration		Concentration	
DIOXIN AND FURAN CONGENERS	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	0.208	2.08E-01	0.15	1.50E-01	0.159	1.59E-01
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	0.233	2.33E-01	0.217	2.17E-01	0.208	2.08E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.261	2.61E-02	0.354	3.54E-02	0.231	2.31E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.146	1.46E-02	9.26	9.26E-01	0.129	1.29E-02
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.173	1.73E-02	0.235	2.35E-02	0.153	1.53E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	10.126	1.01E-01	118.442	1.18E+00	0.355	3.55E-03
OCTACHLORODIBENZO-p-DIOXIN	359.675	3.60E-02	2143.501	2.14E-01	72.013	7.20E-03
2,3,7,8-TETRACHLORODIBENZOFURAN ^a	2.01	2.01E-01	1.652	1.65E-01	1.71	1.71E-01
1,2,3,7,8-PENTACHLORODIBENZOFURAN	0.125	6.25E-03	0.386	1.93E-02	0.124	6.20E-03
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.131	6.55E-02	0.404	2.02E-01	0.129	6.45E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	0.191	1.91E-02	4.679	4.68E-01	0.207	2.07E-02
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	0.127	1.27E-02	3.179	3.18E-01	0.138	1.38E-02
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.207	2.07E-02	5.187	5.19E-01	0.23	2.30E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	0.429	4.29E-03	118.977	1.19E+00	0.173	1.73E-03
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	0.17	1.70E-03	8.313	8.31E-02	0.231	2.31E-03
OCTACHLORODIBENZOFURAN	1.461	1.46E-04	151.114	1.51E-02	0.152	1.52E-05
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^b =		9.68E-07		5.73E-06		7.32E-07
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment is 1.55E-05 mg/kg, the maximum value.						

Table C-2
2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP- 48

Location:	SUMP100		SUMP100		WRSUMP001	
Sample Number:	SUMP100(0-0.5)		SUMP100(3-5)		WRSUMP001(0-.5)	
Date Sampled:	8/7/1998		8/7/1998		8/6/1998	
Depth (ft.):	0-0.50		3-5		0-0.50	
	Concentration		Concentration		Concentration	
DIOXIN AND FURAN CONGENERS	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	1.371	1.37E+00	0.886	8.86E-01	0.2	2.00E-01
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	1.012	1.01E+00	0.848	8.48E-01	0.19	1.90E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	1.399	1.40E-01	1.302	1.30E-01	0.149	1.49E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.781	7.81E-02	0.727	7.27E-02	0.173	1.73E-02
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.928	9.28E-02	0.864	8.64E-02	0.2	2.00E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	14.732	1.47E-01	128.853	1.29E+00	18.198	1.82E-01
OCTACHLORODIBENZO-p-DIOXIN	2666.482	2.67E-01	34472.518	3.45E+00	1131.512	1.13E-01
2,3,7,8-TETRACHLORODIBENZOFURAN ^a	0.986	9.86E-02	0.735	7.35E-02	1.953	1.95E-01
1,2,3,7,8-PENTACHLORODIBENZOFURAN	0.835	4.18E-02	0.777	3.89E-02	0.298	1.49E-02
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.872	4.36E-01	0.811	4.06E-01	0.149	7.45E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	0.803	8.03E-02	0.652	6.52E-02	2.969	2.97E-01
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	0.536	5.36E-02	0.434	4.34E-02	1.92	1.92E-01
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.784	7.84E-02	0.636	6.36E-02	0.207	2.07E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	0.723	7.23E-03	0.576	5.76E-03	12.775	1.28E-01
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	0.9655	9.66E-03	0.678	6.78E-03	1.703	1.70E-02
OCTACHLORODIBENZOFURAN	0.907	9.07E-05	4.526	4.53E-04	12.107	1.21E-03
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^b =		3.91E-06		7.46E-06		1.68E-06
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment is 1.55E-05 mg/kg, the maximum value.						

Table C-2
2,3,7,8-TCDD Toxicity Equivalent Quotient Concentrations of Dioxin and Furan Congeners in Soil at LHAAP- 48

Location:	WRSUMP001		WRSUMP003		WRSUMP003	
Sample Number:	WRSUMP001(3-5)		WRSUMP003(0-.5)		WRSUMP003(3-5)	
Date Sampled:	8/6/1998		8/6/1998		8/6/1998	
Depth (ft.):	3-5		0-0.50		3-5	
	Concentration		Concentration		Concentration	
DIOXIN AND FURAN CONGENERS	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	0.323	3.23E-01	0.289	2.89E-01	0.29	2.90E-01
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	0.275	2.75E-01	0.184	1.84E-01	0.305	3.05E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.431	4.31E-02	0.252	2.52E-02	0.292	2.92E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.251	2.51E-02	1.127	1.13E-01	5.474	5.47E-01
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.289	2.89E-02	0.169	1.69E-02	3.765	3.77E-01
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	22.575	2.26E-01	9.679	9.68E-02	170.246	1.70E+00
OCTACHLORODIBENZO-p-DIOXIN	1275.541	1.28E-01	616.526	6.17E-02	1736.362	1.74E-01
2,3,7,8-TETRACHLORODIBENZOFURAN ^a	1.88	1.88E-01	2.286	2.29E-01	4.933	4.93E-01
1,2,3,7,8-PENTACHLORODIBENZOFURAN	2.026	1.01E-01	0.144	7.20E-03	2.639	1.32E-01
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.21	1.05E-01	0.143	7.15E-02	0.374	1.87E-01
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	3.482	3.48E-01	0.19	1.90E-02	5.052	5.05E-01
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	2.132	2.13E-01	0.537	5.37E-02	1.182	1.18E-01
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.581	5.81E-02	0.17	1.70E-02	1.75	1.75E-01
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	11.94	1.19E-01	1.464	1.46E-02	31.916	3.19E-01
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	1.681	1.68E-02	0.135	1.35E-03	1.573	1.57E-02
OCTACHLORODIBENZOFURAN	13.497	1.35E-03	3.233	3.23E-04	72.002	7.20E-03
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^b =		2.20E-06		1.20E-06		5.38E-06
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment is 1.55E-05 mg/kg, the maximum value.						

Table 2

Concentrations of 2,3,7,8-TCDD Toxicity Equivalent Quotient Dioxin and Furan Congeners in Soil at LHAA- 53(35C)

Longhorn Army Ammunition Plant
Karnack, Texas

Location:		35CSB01		35CSB01	
Sample Number:		35CSB01(0-0.5)		35CSB01(1-3)	
Date Sampled:		7/27/1998		7/27/1998	
Depth (ft.):		0-0.50		1-3	
DIOXIN AND FURAN CONGENERS	TEF	Concentration (ng/kg) TEQ		Concentration (ng/kg) TEQ	
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	1	0.052	5.20E-02	1.267	1.27E+00
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.1	0.033	3.30E-03	10.646	1.06E+00
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.1	0.772	7.72E-02	52.792	5.28E+00
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.1	0.203	2.03E-02	21.791	2.18E+00
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	0.01	20.704	2.07E-01	1453.11	1.45E+01
OCTACHLORODIBENZO-p-DIOXIN	0.0001	141.093	1.41E-02	7068.108	7.07E-01
2,3,7,8-TETRACHLORODIBENZOFURAN	0.1	0.464	4.64E-02	0.476	4.76E-02
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.5	0.042	2.10E-02	0.139	6.95E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	0.1	0.482	4.82E-02	19.746	1.97E+00
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	0.1	0.03	3.00E-03	4.069	4.07E-01
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.1	0.033	3.30E-03	5.037	5.04E-01
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	0.01	3.203	3.20E-02	218.228	2.18E+00
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	0.01	0.178	1.78E-03	11.969	1.20E-01
OCTACHLORODIBENZOFURAN	0.0001	11.88	1.19E-03	904.49	9.04E-02
2,3,7,8-TCDD-TEQ concentration (ng/kg) ^a =		5.31E-07			3.04E-05
Exposure Point Concentration of 2,3,7,8-TCDD TEQ Used in Revised LHAAP-35C(53) Site Evaluation Document = 3.04E-05					

a 2,3,7,8-TCDD TEQ value is sum of TEQ values for congeners in the sample.

TEF: Toxicity Equivalent Factor. Van den Berg, M. et al., 1998, Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife. Environmental Health Perspectives 106(12):775-792.

Table 2

Concentrations of 2,3,7,8-TCDD Toxicity Equivalent Quotient Dioxin and Furan Congeners in Soil at LHAA- 53(35C)

Longhorn Army Ammunition Plant
Karnack, Texas

Location:	35CSB01		SUMP105		SUMP105	
Sample Number:	35CSB01(3-5)		SUMP105(0-0.5)		SUMP105(3-5)	
Date Sampled:	7/27/1998		8/11/1998		8/11/1998	
Depth (ft.):	3-5		0-0.50		3-5	
DIOXIN AND FURAN CONGENERS	Concentration (ng/kg) TEQ		Concentration (ng/kg) TEQ		Concentration (ng/kg) TEQ	
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN	0.038	3.80E-02	0.093	9.30E-02	0.117	1.17E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN	0.348	3.48E-02	0.17	1.70E-02	0.285	2.85E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	2.119	2.12E-01	0.654	6.54E-02	0.159	1.59E-02
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN	0.952	9.52E-02	1.273	1.27E-01	0.189	1.89E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	68.28	6.83E-01	60.154	6.02E-01	3.147	3.15E-02
OCTACHLORODIBENZO-p-DIOXIN	450.139	4.50E-02	17491.922	1.75E+00	340.795	3.41E-02
2,3,7,8-TETRACHLORODIBENZOFURAN	0.394	3.94E-02	0.115	1.15E-02	0.173	1.73E-02
2,3,4,7,8-PENTACHLORODIBENZOFURAN	0.021	1.05E-02	0.051	2.55E-02	0.105	5.25E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	0.856	8.56E-02	0.469	4.69E-02	0.13	1.30E-02
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	0.203	2.03E-02	0.055	5.50E-03	0.087	8.70E-03
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	0.311	3.11E-02	0.08	8.00E-03	0.127	1.27E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	9.51	9.51E-02	2.182	2.18E-02	0.11	1.10E-03
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	0.518	5.18E-03	0.097	9.70E-04	0.14	1.40E-03
OCTACHLORODIBENZOFURAN	51.12	5.11E-03	7.395	7.40E-04	0.1	1.00E-05
2,3,7,8-TCDD-TEQ concentration (ng/kg) ^a =		1.40E-06		2.77E-06		3.53E-07
Exposure Point Concentration of 2,3,7,8-TCDD TEQ Use ng/kg, the maximum value.						

a 2,3,7,8-TCDD TEQ value is sum of TEQ values for conge
TEF: Toxicity Equivalent Factor. Van den Berg, M. et al., 19
PCBs, PCDDs, PCDFs for Humans and Wildlife. Environme

Table C-3
Occurrence, Distribution, and Selection of Chemicals of Potential Concern (COPC)
Soil^a
LHAAP-48

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg		Statistical Distribution ^b	Mean mg/kg	95% UCL ^c mg/kg	Background Screening Concentration ^d mg/kg	Texas	UPL mg/kg	COPC? ^{f,g}	Source-Term
			Detected Concentrations Minimum - Maximum	Reporting Limits Minimum - Maximum					RBSV ^e			Concentration ^h
									mg/kg			mg/kg
Inorganics												
Aluminum	48 / 48	100	1.42E+03 - 1.93E+04	1.24E+01 - 3.79E+01	U	9.39E+03		2.38E+04	1.5E+04	1.89E+04	N (e)	---
Antimony	3 / 45	7	5.12E+00 - 1.10E+01	4.80E+00 - 1.90E+01	L	4.56E+00	4.97E+00	1.60E+00	7.2E+00	1.60E+00	Y	1.10E+01
Arsenic	47 / 48	98	3.37E-01 - 1.07E+01	1.40E-01 - 2.90E+00	U	2.89E+00		6.89E+00	2.0E+01	5.86E+00	N (a)	---
Barium	48 / 48	100	6.59E+00 - 2.51E+03	3.10E+00 - 2.20E+01	NP	2.17E+02	3.10E+02	1.36E+02	9.1E+02	1.16E+02	Y	2.51E+03
Beryllium	1 / 3	33	6.43E-01 - 6.43E-01	5.35E-01 - 5.59E-01	U	3.97E-01		8.85E-01	4.6E+00	7.69E-01	N (a)	---
Cadmium	29 / 48	60	1.46E+00 - 1.14E+01	5.35E-01 - 3.16E+00	NP	2.50E+00	3.20E+00	1.40E+00	5.2E+00	1.40E+00	Y	1.14E+01
Calcium	48 / 48	100	2.26E+02 - 2.34E+03	6.20E+00 - 5.60E+02	U	1.18E+03		3.84E+03	Not Required	2.52E+03	N (b)	---
Chromium	47 / 48	98	3.90E+00 - 4.15E+01	1.10E+00 - 5.65E+00	U	1.35E+01		3.55E+01	5.9E+03	2.90E+01	N (a)	---
Cobalt	47 / 48	98	2.90E-01 - 8.46E+01	8.18E-01 - 5.60E+00	U	8.31E+00		8.34E+00	1.5E+03	7.11E+00	N (a)	---
Copper	46 / 48	96	2.60E+00 - 9.92E+01	1.20E+00 - 3.80E+00	U	1.11E+01		1.04E+01	1.0E+03	8.37E+00	N (a)	---
Iron	48 / 48	100	4.28E+03 - 5.18E+04	1.90E+00 - 1.10E+01	U	1.24E+04		3.49E+04	Not Required	2.79E+04	N (b)	---
Lead	42 / 48	88	9.45E+00 - 1.51E+02	3.21E-01 - 1.90E+01	U	2.01E+01		2.03E+01	5.0E+02	1.78E+01	N (a)	---
Magnesium	48 / 48	100	6.53E+01 - 1.83E+03	1.24E+01 - 5.60E+02	U	7.61E+02		1.59E+03	Not Required	1.24E+03	N (b)	---
Manganese	48 / 48	100	8.56E+00 - 1.42E+03	6.20E-01 - 1.90E+00	U	2.57E+02		2.24E+03	1.7E+03	1.34E+03	N (a)	---
Mercury	9 / 48	19	2.35E-02 - 3.12E-01	2.40E-02 - 1.80E-01	NP	3.84E-02	4.96E-02	1.34E-01	1.1E-02	1.10E-01	N (e)	---
Nickel	3 / 3	100	5.40E+00 - 1.10E+01	4.30E+00 - 4.50E+00	U	8.03E+00		1.13E+01	1.9E+02	9.40E+00	N (a)	---
Potassium	48 / 48	100	9.22E+01 - 1.10E+03	1.24E+02 - 5.60E+02	U	5.36E+02		5.46E+02	Not Required	4.61E+02	N (b)	---
Selenium	14 / 48	29	2.00E-01 - 1.76E+00	1.30E-01 - 1.26E+00	U	4.59E-01		6.96E+00	1.3E+02	5.61E+00	N (a)	---
Silver	15 / 48	31	2.75E-02 - 1.20E+00	2.40E-02 - 1.90E+00	U	2.40E-01		3.70E-01	4.7E+01	3.70E-01	N (a)	---
Strontium	43 / 48	90	5.73E+00 - 5.14E+02	5.30E+00 - 1.90E+01	U	5.27E+01		3.17E+01	1.2E+04	2.48E+01	N (a)	---
Vanadium	3 / 3	100	1.70E+01 - 2.80E+01	5.30E+00 - 5.60E+00	U	2.37E+01		5.29E+01	4.8E+01	4.44E+01	N (a)	---
Zinc	48 / 48	100	6.40E+00 - 2.07E+02	6.20E-01 - 2.20E+00	U	4.60E+01		2.94E+01	5.9E+03	2.45E+01	N (a)	---
Dioxins/Furans												
2,3,7,8-TCDD - Total TEQ	15 / 15	100	3.18E-07 - 1.55E-05	NA - NA	U	4.56E-06	9.53E-06	4.41E-06	3.90E-06	j 1.55E-05	Y	1.55E-05
Polychlorinated Biphenyls (PCBs)												
Aroclor 1254	1 / 3	33	6.60E-02 - 6.60E-02	3.60E-02 - 3.70E-02	U	3.42E-02			1.0E+01		N (a)	---
Semivolatile Organics												
2-Methylnaphthalene	3 / 48	6	1.64E+00 - 1.84E+00	3.28E-01 - 7.20E-01	U	2.92E-01			5.0E+01		N (a)	---
Acenaphthene	1 / 48	2	3.00E-01 - 3.00E-01	3.28E-01 - 7.20E-01	U	1.96E-01			2.2E+00		N (a)	---
Anthracene	1 / 48	2	5.90E-01 - 5.90E-01	3.60E-01 - 1.39E+00	U	2.96E-01			3.5E+00		N (a)	---
Benzo(a)anthracene	3 / 48	6	7.50E-02 - 1.90E+00	3.00E-01 - 8.33E-01	NP	2.33E-01	2.76E-01	1.53E-02	6.3E-01	1.53E-02	N (f)	---
Benzo(a)pyrene	2 / 48	4	8.70E-02 - 1.60E+00	1.80E-01 - 3.85E+00	U	3.40E-01		1.54E-02	6.3E-02	1.54E-02	N (d,f)	---
Benzo(b)fluoranthene	4 / 48	8	1.90E-01 - 2.90E+00	3.60E-01 - 2.78E+00	NP	5.67E-01	6.76E-01	1.53E-02	6.3E-01	1.53E-02	N (f)	---
Benzo(ghi)perylene	2 / 48	4	6.66E-01 - 6.70E-01	3.60E-01 - 5.56E+00	U	9.44E-01		1.23E-02	4.1E+02	1.23E-02	N (a)	---
Benzo(k)fluoranthene	2 / 48	4	9.80E-02 - 1.10E+00	3.60E-01 - 2.78E+00	U	5.17E-01		1.30E-02	6.3E+00	1.30E-02	N (a)	---
Benzoic Acid	1 / 14	7	3.40E-01 - 3.40E-01	8.90E-01 - 3.60E+00	U	9.46E-01			6.2E+04		N (a)	---
bis(2-Ethylhexyl)phthalate	8 / 48	17	4.20E-02 - 4.50E-01	1.15E-01 - 7.56E+00	U	2.29E-01			1.7E+01		N (a)	---
Butyl benzyl phthalate	2 / 48	4	2.23E-01 - 2.90E-01	3.33E-01 - 3.85E+00	U	3.18E-01			3.1E+03		N (a)	---
Chrysene	3 / 48	6	1.80E-01 - 2.20E+00	3.60E-01 - 1.39E+01	U	2.28E+00		1.51E-02	6.3E+01	1.51E-02	N (a)	---
Dibenzo(a,h)anthracene	2 / 48	4	2.30E-01 - 6.55E-01	3.60E-01 - 5.56E+00	U	9.28E-01			6.3E-02		N (d,f)	---
Dibenzofuran	1 / 48	2	1.70E-01 - 1.70E-01	3.60E-01 - 2.78E+00	U	5.04E-01			2.0E+01		N (a)	---
Diethyl phthalate	9 / 48	19	1.00E-01 - 1.83E+00	1.61E-01 - 1.28E+00	U	2.75E-01			1.2E+04		N (a)	---
Dimethyl phthalate	5 / 48	10	3.30E-01 - 9.75E-01	3.60E-01 - 7.20E-01	U	3.37E-01			1.2E+04		N (a)	---
di-n-Butyl phthalate	3 / 48	6	6.70E-02 - 8.30E-02	3.29E-01 - 6.23E+00	U	1.02E+00			1.5E+03		N (a)	---
Fluoranthene	6 / 48	13	1.10E-01 - 3.60E+00	3.60E-01 - 1.39E+00	U	3.63E-01		2.29E-02	5.5E+02	2.29E-02	N (a)	---
Fluorene	1 / 48	2	2.50E-01 - 2.50E-01	3.60E-01 - 1.39E+00	U	2.88E-01			4.6E+01		N (a)	---
Indeno(1,2,3-cd)pyrene	3 / 48	6	2.00E-01 - 7.50E-01	3.60E-01 - 2.78E+00	NP	5.12E-01	5.83E-01	1.43E-02	6.3E-01	1.43E-02	N (f)	---
Naphthalene	4 / 48	8	1.10E-01 - 4.39E+00	3.28E-01 - 7.20E-01	U	4.42E-01			1.8E+01		N (a)	---
Phenanthrene	5 / 48	10	9.70E-02 - 2.90E+00	3.60E-01 - 1.28E+00	NP	3.75E-01	4.68E-01		2.5E+00		N (f)	---
Pyrene	6 / 48	13	8.00E-02 - 2.40E+00	3.60E-01 - 1.39E+00	U	3.23E-01		1.94E-02	1.5E+01	1.94E-02	N (a)	---

Table C-3
Occurrence, Distribution, and Selection of Chemicals of Potential Concern (COPC)
Soil^a
LHAAP-48

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg		Statistical Distribution ^b	Mean mg/kg	95% UCL ^c mg/kg	Background	Texas	UPL mg/kg	COPC? ^{f,g}	Source-Term
			Detected Concentrations Minimum - Maximum	Reporting Limits Minimum - Maximum				Screening Concentration ^d mg/kg	RBSV ^e mg/kg			Concentration mg/kg
Volatile Organics												
1,1-Dichloroethene	1 / 48	2	2.00E-03 - 2.00E-03	5.00E-03 - 1.10E-02	U	3.05E-03			2.7E+01		N (a)	---
2-Butanone	4 / 48	8	9.00E-03 - 3.60E-02	1.10E-02 - 6.60E-02	U	2.32E-02			2.6E+03		N (a)	---
Acetone	1 / 48	2	5.10E-03 - 5.10E-03	6.00E-03 - 4.10E-01	U	2.75E-02			1.7E+02		N (a)	---
Carbon disulfide	8 / 48	17	1.00E-03 - 1.45E-01	5.00E-03 - 1.10E-02	U	7.52E-03			1.0E+02		N (a)	---
Ethylbenzene	1 / 48	2	2.00E-03 - 2.00E-03	5.00E-03 - 1.10E-02	U	3.05E-03			4.3E+02		N (a)	---
Styrene	1 / 48	2	3.00E-03 - 3.00E-03	5.00E-03 - 1.10E-02	U	3.07E-03			1.3E+03		N (a)	---
Tetrachloroethene	3 / 48	6	9.00E-03 - 2.04E-01	5.00E-03 - 1.10E-02	U	7.96E-03			6.0E+00		N (a)	---
Toluene	1 / 48	2	2.00E-03 - 2.00E-03	5.00E-03 - 1.10E-02	U	3.05E-03			1.7E+02		N (a)	---
trans-1,3-Dichloropropene	2 / 48	4	3.00E-03 - 1.00E-02	5.00E-03 - 1.10E-02	U	3.22E-03			1.8E+00		N (a)	---
Trichloroethene	6 / 48	13	1.00E-03 - 4.55E-02	5.00E-03 - 1.10E-02	U	4.91E-03			3.7E+00		N (a)	---
Vinyl chloride	1 / 48	2	4.97E-01 - 4.97E-01	1.10E-02 - 3.30E-02	U	2.27E-02			3.6E-02		Y	4.97E-01
Xylenes, Total	1 / 48	2	1.80E-02 - 1.80E-02	5.00E-03 - 1.10E-02	U	3.38E-03			5.8E+01		N (a)	---

^a Surface soil is defined as the interval less than or equal to 15 feet below the ground surface. Soil samples were classified on the basis of the end depth of the sample.

^b Statistical Distribution: U = Distribution not determined if chemical is not selected as a COPC, or if sample size is less than 5; L = Lognormal distribution; NP = nonparametric distribution.

^c 95% Upper confidence limit (UCL) calculated for COPC using bootstrapping (2000 replications).

^d Background screening concentrations are based on the 95% upper prediction limit (UPL) of the total soil background data set, calculated for the combined depth intervals (i.e., 0-0.5 feet and 1.5-2.5 feet) from Shaw, 2004c, Final Background Soil Study Report, Longhorn Army Ammunition Plant, July.

^e Based on Texas Risk-Based Screening Values (RBSV) for soil, March 2006 update. Values are based on a cancer risk of 1E-6 and a hazard index of 0.1

^f N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.

^g Rationale for exclusion of chemical as a COPC:

(a) = maximum detected concentration is below or equal to risk-based screening concentration

(b) = essential nutrient; no screening value available/required

(c) = chemical concentration is below or equal to background screening concentration.

(d) = chemical is detected infrequently (i.e., < 5% frequency of detection).

(e) = maximum concentration of chemical is above the Background Screening Concentration but is consistent with background based on geochemical evaluation (Attachment B)

(f) = chemical is not expected to be associated with pyrotechnic and illuminator manufacturing operations at LHAAP-48.

^h Concentration used in the risk assessment is the maximum detected concentration.

ⁱ Based on RBSV for total chromium.

^j Based on the medium-specific screening level (MSSL) for dioxin (2,3,7,8-TCDD) from EPA Region 6 (USEPA Region 6, 2004, Human Health Medium-Specific Screening Levels 2004-2005, December).

NA = Not applicable

TEQ = Toxicity equivalency

UPL = Upper prediction limit of the Shaw total soil background dataset (Shaw, 2004c).

mg/kg = milligram per kilogram

Table C-4
Comparison of Metal Concentrations in LHAAP-48 Soil Samples to Background Concentrations

Metal	Basis for Background Comparison	Are LHAAP-45 Concentrations Different from Background? ^d		Comment
		p value ^c		
Aluminum	WRS Test ^a , Geochem ^b	0.005000	No	(1)
Antimony	WRS Test ^a , Geochem ^b	0.000000	Yes	(2)
Barium	WRS Test ^a , Geochem ^b	0.000000	Yes	
Cadmium	WRS Test ^a , Geochem ^b	0.000000	Yes	(3)
Mercury	WRS Test ^a , Geochem ^b	0.014442	No	(1)

Footnotes and Abbreviations:

^a Wilcoxon Rank Sum statistical test

^b Geochem: Comparison to background based on geochemical relationships (Attachment B)

^c Values shown in Attachment B.

^d Difference is considered significant with 95% confidence if $p > 0.05$.

Comments:

- (1) All samples consistent with background concentrations based on geochemical relationships (Attachment B, Table 2-6).
- (2) Sample population exceeds background based on statistical test (Attachment A) and three samples represent anomalous geochemical relationships (Attachment B, Table 2-6).
- (3) Sample population exceeds background based on statistical test (Attachment A) and seven samples represent anomalous geochemical relationships (Attachment B, Table 2-6).

Table C-5
Exposure Factors Used to Estimate Intake of COPCs
LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Residential Exposure Pathway		
General Factors	Factor Value	Reference
Exposure Frequency, EF (days/year or event/year, dermal)	350	a
Exposure Duration, ED (year) - Adult	24	a
Exposure Duration, ED (year) - Child	6	a
Exposure Duration, ED (year) - carcinogens, Adult	30	b
Body Weight, BW (kg) - Adult	70	a
Body Weight, BW (kg) - Child	15	a
Averaging Time-Noncarcinogens, ATs (year) - Adult	24	a
Averaging Time-Noncarcinogens, ATs (year) - Child	6	a
Averaging Time-carcinogens, ATc (year)	70	a
Averaging Time, Age-adjusted, Residential, dermal (cadmium) (year)	30	b
Ingestion of Soil		
Age-Adjusted Soil Ingestion Rate, IF _{adj} (mg-year/kg-day)	114	a
Dermal Exposure to Soil		
Soil-to-Skin Adherence Factor, AF (mg/cm ² -event)	0.2	a
Averaging Time-Noncarcinogens, (dermal, child, resident) ATs (year)	6	a
Age-Adjusted Averaging Time (residential, dermal) ATs (year)	30	b, Cadmium only
Body Weight (residential, child, carcinogens), BW (kg)	15	a
Age-Adjusted Dermal Factor (carcinogens, resident) DF _{adj} (mg-yr/kg-event)	352	b
Exposure Duration (dermal, child, resident), ED (year)	6	a
Exposed Skin Surface Area, SA (cm ²) - Child	2200	a
Exposed Skin Surface Area, SA (cm ²) - Adult	2500	a

a TCEQ-rrr: Texas Commission on Environmental Quality (TCEQ) 30 TAC Sec. 335.567 as updated through March 2005.

b Value provided during TCEQ review of August 2006.

Table C-6
Toxicity Values for COPCs
Baseline Risk Assessment for the LHAAP-48 Site
LHAAP
Karnack, Texas

Chemical	Weight of Evidence ^a	Ref.	Oral Slope Factor SFO 1/(mg/kg-day)	Ref.	Inhalation Unit Risk Factor, URF ^b 1/(ug/m ³)	Ref.	Inhalation Slope Factor SFI 1/(mg/kg-day)	Ref.	Oral Reference Dose, RfDo (mg/kg-day)	Ref.	Inhalation Reference Conc., RfC (mg/m ³)	Ref.	GI Absorption Factor, ABS.gi (unitless)	Ref.	Relative Dermal Absorption Factor, ABS.d (unitless)	Ref.
Inorganic Compounds																
Antimony	NA	TCEQ-rrr	NA	NA	NA	NA	NA	NA	4.0E-04	I	5.0E-04	TCEQ-rrr	1.50E-01	TCEQ-rrr	1.00E-02	TCEQ-rrr
Barium	D	I	NA	NA	NA	NA	NA	NA	2.0E-01	I	5.0E-04	TCEQ-rrr	7.00E-02	TCEQ-rrr	1.00E-02	TCEQ-rrr
Cadmium	B1	I	NA	NA	1.8E-03	I	6.3E+00	TCEQ-rrr	1.0E-03	I	ND	TCEQ-rrr	2.50E-02	TCEQ-rrr	1.00E-03	TCEQ-rrr
Semivolatile Organic Compounds																
2,3,7,8-TCDD - Total TEQ	ND	NA	1.5E+05	EPA-06, H	4.3E+01	EPA-06, H	1.5E+05	EPA-06, H	ND	EPA-06, H	ND	EPA-06, H	5.00E-01	TCEQ-trrp	3.00E-02	TCEQ-trrp
Volatile Organic Compounds																
Vinyl Chloride	A	I	1.5E+00	I	8.8E-06	I	3.1E-02	TCEQ-rrr	3.0E-03	I	1.0E-01	TCEQ-rrr	1.00E+00	TCEQ-rrr	0.00E+00	TCEQ-rrr

^a Weight of Evidence for carcinogenicity of chemical provided in Reference I. D indicates chemical is not classifiable as to human carcinogenicity, B1 indicates chemical is a probable human carcinogen based on limited data, A indicates a human carcinogen.

^b The URF value for 2,3,7,8-TCDD was calculated using the equation: $URF(\mu g/m^3)^{-1} = SF_{inh} (mg/kg\text{-}day)^{-1} \times 20 m^3/day / (70 kg \times 1000 \mu g/mg)$ as provided in TCEQ-rrr documents.

EPA-06: USEPA, 2006: Human Health Medium-Specific Screening Levels, U. S. Environmental Protection Agency, Region 6, November 2004, accessed online in January 2006.

H: Health Effects Assessment Summary Tables (HEAST), U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, July 1997, adopted in USEPA, 2006.

I: Integrated Risk Information System (IRIS) (Online, EPA, 2006).

NA: Not Applicable

ND: No Data

Ref.: Reference

TCEQ-rrr: Texas Commission on Environmental Quality (TCEQ) 30 TAC Sec. 335.567 as updated through March 2006

TCEQ-trrp: Texas Commission on Environmental Quality (TCEQ) 30 TAC Sec. 350 as updated through March 2006

Table C-7a
Incremental Lifetime Cancer Risk (ILCR) for Potential Ingestion Exposure of Future Residents to
Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral Slope factor, SF 1/(mg/kg/d)	Weight of Evidence	Intake Dose, ID (mg/kg/d)	Incremental Lifetime Cancer Risk, ILCR
Antimony	1.10E+01	NA	NA	1.72E-05	0.00E+00
Barium	2.51E+03	NA	D	3.92E-03	0.00E+00
Cadmium	1.14E+01	NA	B1	1.78E-05	0.00E+00
2,3,7,8-TCDD - Total TEQ	1.55E-05	1.50E+05	ND	2.42E-11	3.63E-06
Vinyl Chloride	4.97E-01	1.50E+00	A	7.76E-07	1.16E-06
TOTAL PATHWAY CANCER RISK					4.80E-06

Table C-7b
Hazard Index (HI) for Potential Ingestion Exposure of Future Residents to
Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral RfD (mg/kg/d)	Intake Dose, ID in (mg/kg/d)	Hazard Quotient HQ
Antimony	1.10E+01	4.00E-04	4.01E-05	1.00E-01
Barium	2.51E+03	2.00E-01	9.15E-03	4.57E-02
Cadmium	1.14E+01	1.00E-03	4.15E-05	4.15E-02
2,3,7,8-TCDD - Total TEQ	1.55E-05	ND	5.65E-11	0.00E+00
Vinyl Chloride	4.97E-01	3.00E-03	1.81E-06	6.04E-04
TOTAL PATHWAY HAZARD INDEX				1.88E-01

NA: Not applicable

ND: No data available

Table C-8a
Incremental Lifetime Cancer Risk (ILCR) for Potential Inhalation Exposure of Future Resident to
Airborne Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs, mg/kg	Weight of Evidence	Unit Risk Factor, URF 1/(microg/m ³)	Exposure Adjusted Air Concentration (mg/m ³)	Incremental Lifetime Cancer Risk, ILCR
Antimony	1.10E+01	NA	NA	9.76E-07	0.00E+00
Barium	2.51E+03	D	NA	2.23E-04	0.00E+00
Cadmium	1.14E+01	B1	1.8E-03	1.01E-06	1.82E-09
2,3,7,8-TCDD - Total TEQ	1.55E-05	ND	4.3E+01	8.99E-10	3.85E-08
Vinyl Chloride	4.97E-01	A	8.8E-06	6.41E+00	5.64E-05
TOTAL PATHWAY CANCER RISK					5.65E-05

Table C-8b
Hazard Index (HI) for Potential Inhalation Exposure of Future Resident to
Airborne Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs, mg/kg	Reference Conc., RfC (mg/m ³)	Exposure Adjusted Air Concentration (mg/m ³)	Hazard Quotient HQ
Antimony	1.10E+01	5.0E-04	2.28E-09	4.56E-06
Barium	2.51E+03	5.0E-04	5.20E-07	1.04E-03
Cadmium	1.14E+01	ND	2.36E-09	0.00E+00
2,3,7,8-TCDD - Total TEQ	1.55E-05	ND	2.10E-12	0.00E+00
Vinyl Chloride	4.97E-01	1.0E-01	1.50E-02	1.50E-01
TOTAL PATHWAY HAZARD INDEX				1.51E-01

NA: Not applicable
 ND: No data available

Table C-9a
Incremental Lifetime Cancer Risk (ILCR) for Potential Dermal Exposure of Future Residents to
Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Gastrointestinal		Dermal Slope factor, SF _d 1/(mg/kg/d)	Absorption Factor, ABS _d (unitless)	Weight of Evidence	Dermal Absorbed Dose Dose, DAD (mg/kg/d)	Incremental Lifetime Cancer Risk, ILCR
		Oral Slope factor, SF 1/(mg/kg/d)	Absorption Factor, ABS _{GI} (unitless)					
Antimony	1.10E+01	NA	1.50E-01	NA	1.00E-02	NA	5.30E-07	0.00E+00
Barium	2.51E+03	NA	7.00E-02	NA	1.00E-02	D	1.21E-04	0.00E+00
Cadmium	1.14E+01	NA	2.50E-02	NA	1.00E-03	B1	5.50E-08	0.00E+00
2,3,7,8-TCDD - Total TEQ	1.55E-05	1.50E+05	5.00E-01	1.50E+05	3.00E-02	ND	2.24E-12	3.36E-07
Vinyl Chloride	4.97E-01	1.50E+00	1.00E+00	1.50E+00	0.00E+00	A	0.00E+00	0.00E+00
TOTAL PATHWAY CANCER RISK								3.36E-07

Table C-9b
Hazard Index (HI) for Potential Dermal Exposure of Future Residents to
Chemicals from Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Gastrointestinal		Dermal RfD (mg/kg/d)	Absorption Factor, ABS _d (unitless)	Dermal Absorbed Dose Dose, DAD (mg/kg/d)	Hazard Quotient HQ
		Oral RfD (mg/kg/d)	Absorption Factor, ABS _{GI} (unitless)				
Antimony	1.10E+01	4.00E-04	1.50E-01	6.00E-05	1.00E-02	3.09E-06	5.16E-02
Barium	2.51E+03	2.00E-01	7.00E-02	1.40E-02	1.00E-02	7.06E-04	5.04E-02
Cadmium	1.14E+01	1.00E-03	2.50E-02	2.50E-05	1.00E-03	1.28E-07	5.13E-03
2,3,7,8-TCDD - Total TEQ	1.55E-05	ND	5.00E-01	ND	3.00E-02	1.31E-11	0.00E+00
Vinyl Chloride	4.97E-01	3.00E-03	1.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00
TOTAL PATHWAY HAZARD INDE							1.07E-01

NA: Not applicable

ND: No data available

Table C-10a
Exposures and Incremental Lifetime Cancer Risks for Potential Expoure of Future Resident to
Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical	Source Term Concentration (mg/kg)	Soil Ingestion Cancer Risk (ILCR)	Soil Inhalation Cancer Risk (ILCR)	Dermal Cancer Risk (ILCR)
Antimony	1.10E+01	0.00E+00	0.00E+00	0.00E+00
Barium	2.51E+03	0.00E+00	0.00E+00	0.00E+00
Cadmium	1.14E+01	0.00E+00	1.82E-09	0.00E+00
2,3,7,8-TCDD - Total TEQ	1.55E-05	3.63E-06	3.85E-08	3.36E-07
Vinyl Chloride	4.97E-01	1.16E-06	5.64E-05	0.00E+00
Total Pathway ILCR		4.80E-06	5.65E-05	3.36E-07
Total ILCR ^a				6.E-05

Table C-10b
Exposures and Noncancer Hazards for Potential Expoure of Future Resident to
Soil at the LHAAP-48 Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical	Source Term Concentration (mg/kg)	Soil Ingestion HQ	Soil Inhalation HQ	Dermal HQ
Antimony	1.10E+01	1.00E-01	4.56E-06	5.16E-02
Barium	2.51E+03	4.57E-02	1.04E-03	5.04E-02
Cadmium	1.14E+01	4.15E-02	0.00E+00	5.13E-03
2,3,7,8-TCDD - Total TEQ	1.55E-05	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	4.97E-01	6.04E-04	1.50E-01	0.00E+00
Pathway Hazard Index (HI)		1.88E-01	1.51E-01	1.07E-01
Total HI ^a				4.E-01

^a Total value reported to one significant figure

Attachment 1
Statistical Comparison to Background Concentrations

Table 1
Concentrations of Selected Metals in Soil for Comparison to Background

Data Type	Al (mg/kg)	Sb (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Site 48	19300	2.4	2510	0.2675	0.012
Site 48	15600	2.54	1620	0.268	0.01225
Site 48	15300	2.59	1271.5	0.2795	0.0125
Site 48	14600	2.59	403	0.31	0.0125
Site 48	13700	2.64	327	0.335	0.0125
Site 48	13400	2.75	251	0.34	0.013
Site 48	13300	2.77	224	0.36	0.013
Site 48	13200	2.83	195	0.375	0.013
Site 48	13000	2.87	190	0.49	0.0135
Site 48	12800	3.06	179	0.4975	0.0135
Site 48	12600	3.1	152	0.7	0.0135
Site 48	12500	3.19	149	0.75	0.0135
Site 48	12500	3.26	143	0.8	0.01375
Site 48	12400	3.35	131	0.95	0.014
Site 48	12200	3.4	126	1.2	0.014
Site 48	11600	3.42	125	1.26	0.014
Site 48	11000	3.47	121	1.27	0.014
Site 48	10600	3.48	120	1.33	0.014
Site 48	10300	3.6	120	1.58	0.014
Site 48	10300	3.73	112	11.4	0.014
Site 48	10100	3.75	108	5.55	0.0145
Site 48	10000	3.755	100	5.55	0.015
Site 48	9570	3.84	100	5.17	0.015
Site 48	8700	3.89	98.2	4.92	0.0195
Site 48	8300	4.41	90.3	4.735	0.03
Site 48	8290	4.49	86.85	4.55	0.0385
Site 48	8095	4.7	86	4.44	0.0425
Site 48	7910	4.81	85.4	4.41	0.043
Site 48	7810	4.9	83.8	4.35	0.0435
Site 48	7590	4.9	83.1	4.25	0.0455
Site 48	7340	5.05	82.5	3.91	0.05
Site 48	7200	5.15	77.9	3.55	0.055
Site 48	6900	5.3	77.6	3.46	0.055
Site 48	6830	5.35	76.4	3.42	0.055
Site 48	6720	5.65	71.2	3.4	0.06
Site 48	6700	6	68.4	3.23	0.065
Site 48	6520	6.05	66.8	2.82	0.065
Site 48	6320	6.3	66	2.73	0.065
Site 48	6180	6.85	65.5	2.69	0.09
Site 48	6140	7.6	64.7	2.63	0.312
Site 48	5920	7.8	58.5	2.22	0.06
Site 48	5730	9.5	54.8	2.22	0.057
Site 48	5400	11	43.1	2.13	0.057
Site 48	5400	7.96	41.7	2.12	0.055
Site 48	5030	5.12	36.8	1.8825	0.053
Site 48	4680		32.2	1.76	0.051
Site 48	3550		18.5	1.555	0.0425
Site 48	1420		6.59	1.46	0.0235
BKG	1800	0.15	17.7	0.026	0.02
BKG	1850	0.15	26.8	0.027	0.023
BKG	1900	0.15	28.9	0.027	0.026

Table 1
Concentrations of Selected Metals in Soil for Comparison to Background

Data Type	Al (mg/kg)	Sb (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
BKG	2080	0.15	29.7	0.027	0.027
BKG	2280	0.15	31.1	0.027	0.03
BKG	2510	0.16	31.8	0.028	0.032
BKG	2530	0.16	37.8	0.028	0.033
BKG	2690	0.16	38.4	0.029	0.034
BKG	2930	0.16	39.9	0.031	0.035
BKG	2990	0.16	41.8	0.031	0.036
BKG	3030	0.16	42.8	0.032	0.037
BKG	3210	0.16	44.7	0.033	0.037
BKG	3330	0.16	45	0.033	0.038
BKG	3560	0.16	49.1	0.033	0.039
BKG	3710	0.16	49.5	0.034	0.041
BKG	3780	0.16	51.7	0.053	0.042
BKG	3850	0.16	57.5	0.097	0.044
BKG	3940	0.16	59.2	0.1	0.045
BKG	3980	0.16	67.8	0.12	0.046
BKG	4000	0.16	72.6	0.13	0.047
BKG	4130	0.16	72.8	0.14	0.047
BKG	4390	0.16	94.8	0.15	0.047
BKG	4700	0.16	98.7	0.17	0.059
BKG	5180	0.17	107	0.19	0.06
BKG	5850	0.17	124	0.35	0.06
BKG	5980	0.17	130	0.46	0.072
BKG	6050	0.65	166	0.84	0.088
BKG	16300	0.94	181	1.4	0.12
BKG	3110	0.15	25.6	0.025	0.012
BKG	4250	0.16	39.8	0.027	0.015
BKG	6160	0.16	39.9	0.028	0.017
BKG	6840	0.16	40.1	0.028	0.018
BKG	7170	0.16	40.3	0.028	0.024
BKG	7940	0.16	40.6	0.029	0.025
BKG	8310	0.16	42.1	0.029	0.027
BKG	8380	0.16	42.5	0.029	0.029
BKG	8690	0.17	44.6	0.031	0.029
BKG	9030	0.17	45	0.031	0.03
BKG	9510	0.17	45.1	0.031	0.031
BKG	9660	0.17	46.8	0.032	0.032
BKG	10200	0.17	47.7	0.032	0.035
BKG	10300	0.17	48.9	0.033	0.036
BKG	10700	0.17	55	0.033	0.036
BKG	10700	0.18	55.1	0.034	0.039
BKG	11300	0.18	55.6	0.044	0.043
BKG	11600	0.31	57.2	0.069	0.046
BKG	11700	0.32	58.4	0.091	0.046
BKG	11700	0.32	58.4	0.1	0.055
BKG	12200	0.35	64.5	0.11	0.056
BKG	12900	0.38	64.7	0.12	0.056
BKG	12900	0.4	65.6	0.13	0.058
BKG	14600	0.4	70.2	0.15	0.061
BKG	14700	0.56	75.3	0.17	0.064
BKG	16100	1.3	76.2	0.22	0.083

Table 1
Concentrations of Selected Metals in Soil for Comparison to Background

Data Type	Al (mg/kg)	Sb (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
BKG	21100	1.4	76.3	0.35	0.25
BKG	22500	1.6	101	0.4	0.36

Al: aluminum

Ba: barium

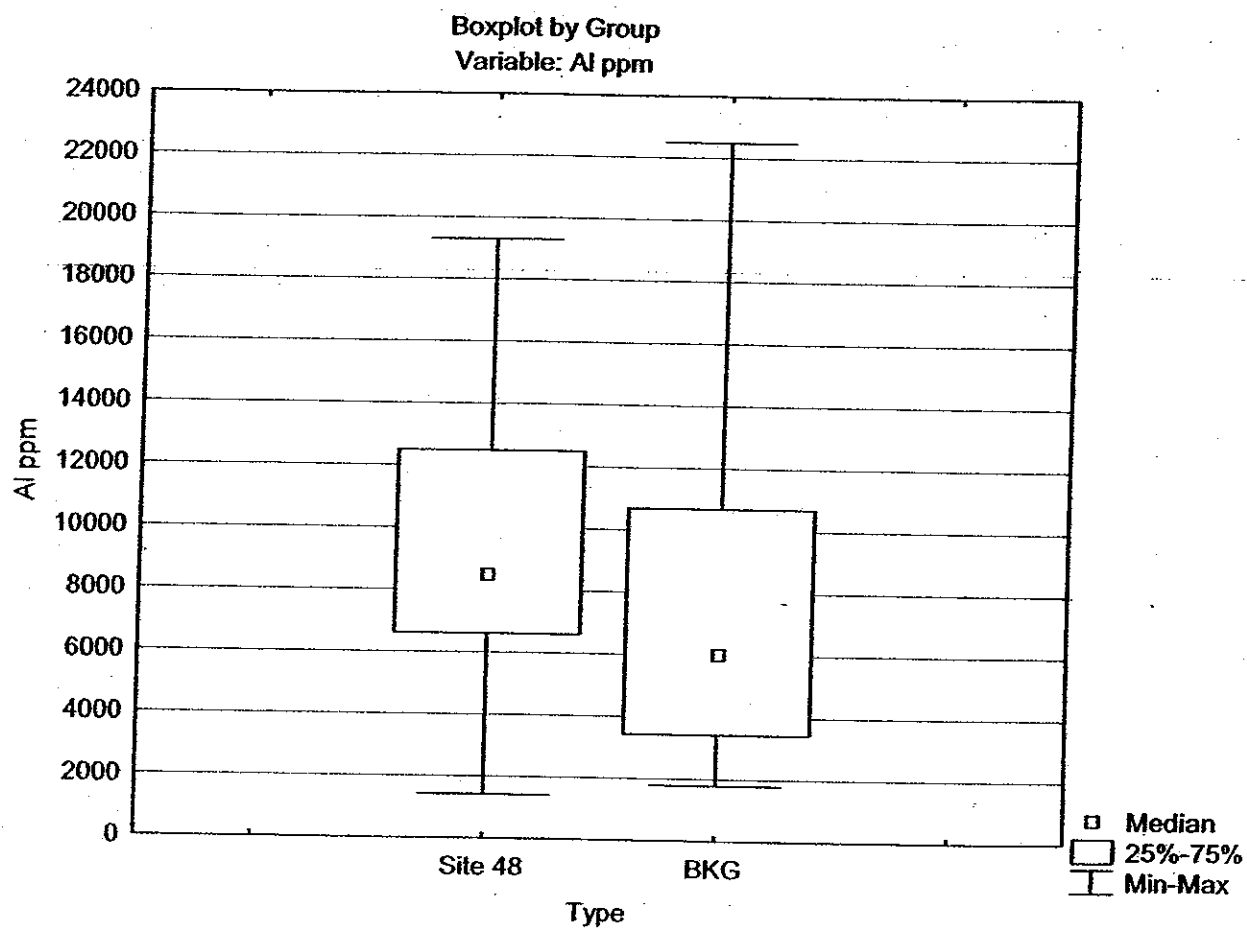
BKG: background concentrations

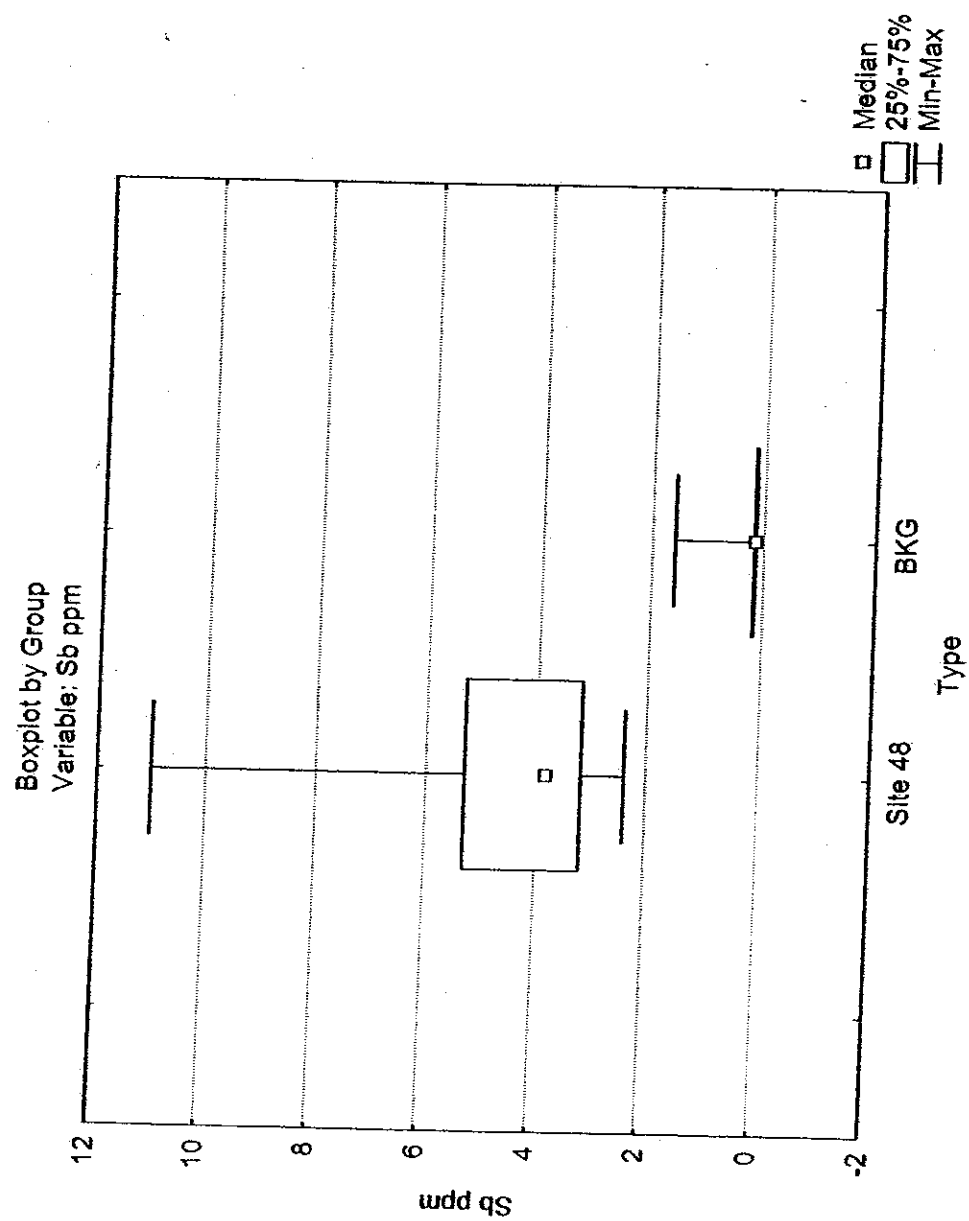
Cd: cadmium

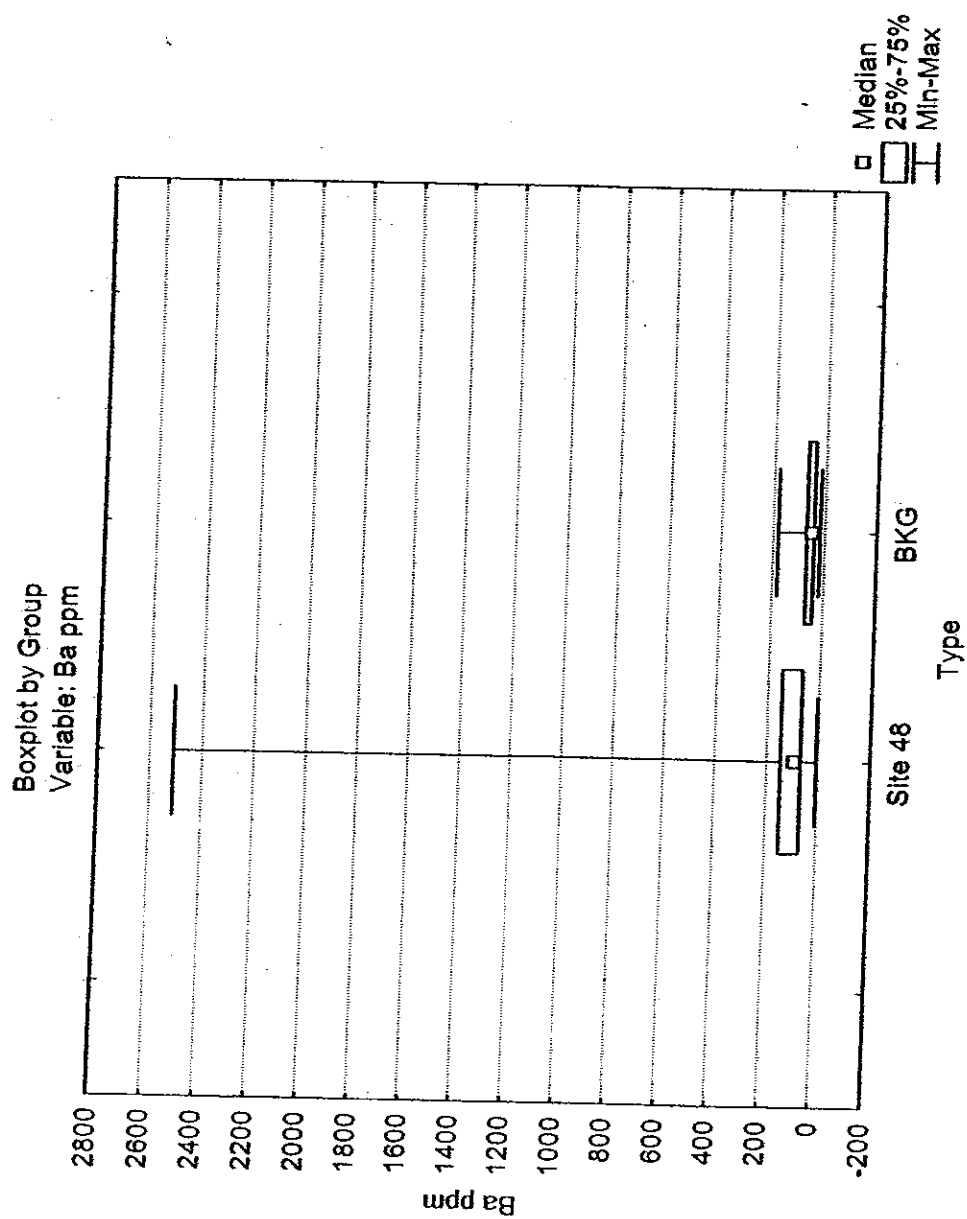
Hg: mercury

Sb: antimony

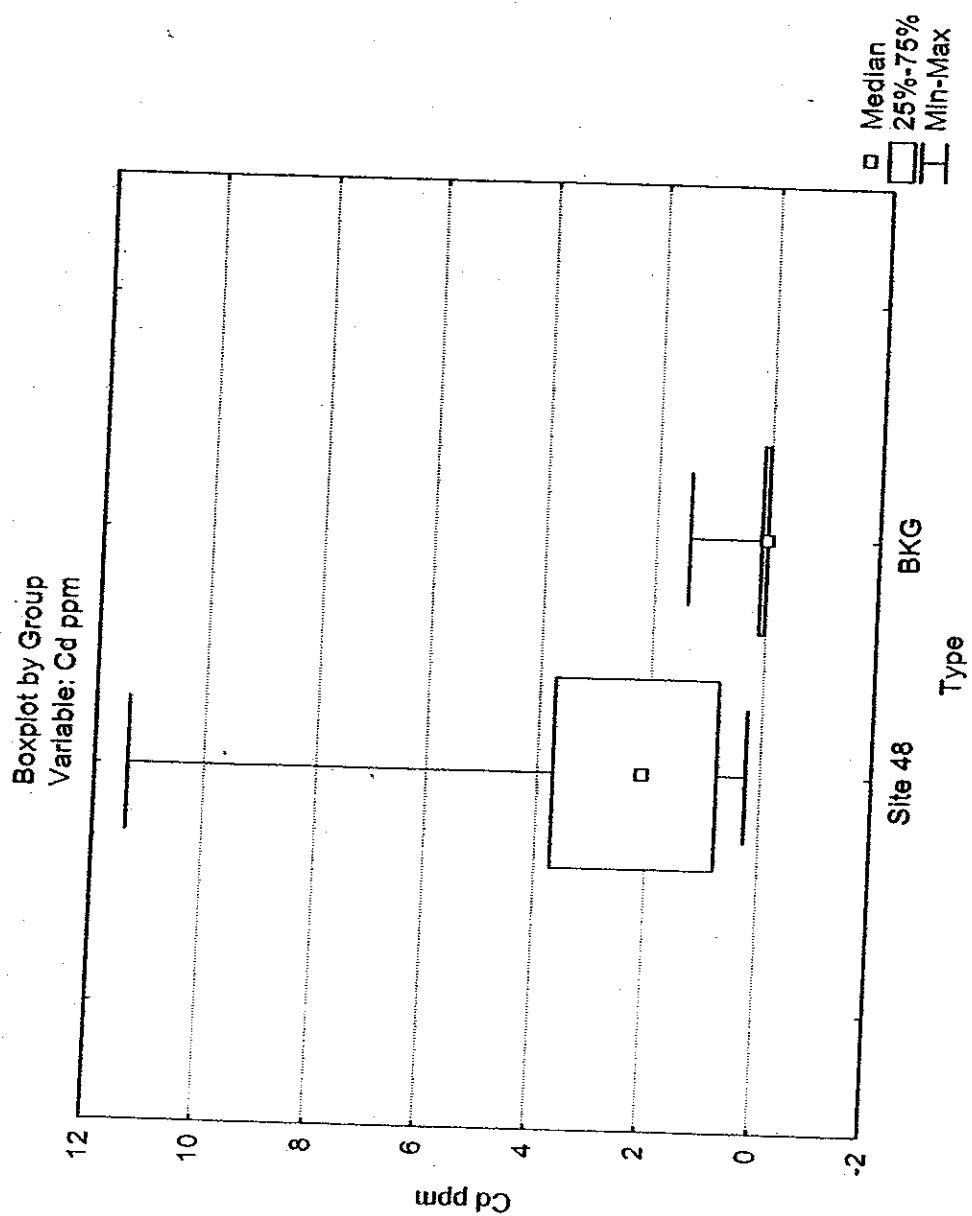
ppm: parts per million. All soil concentrations are expressed in units of mg/kg.

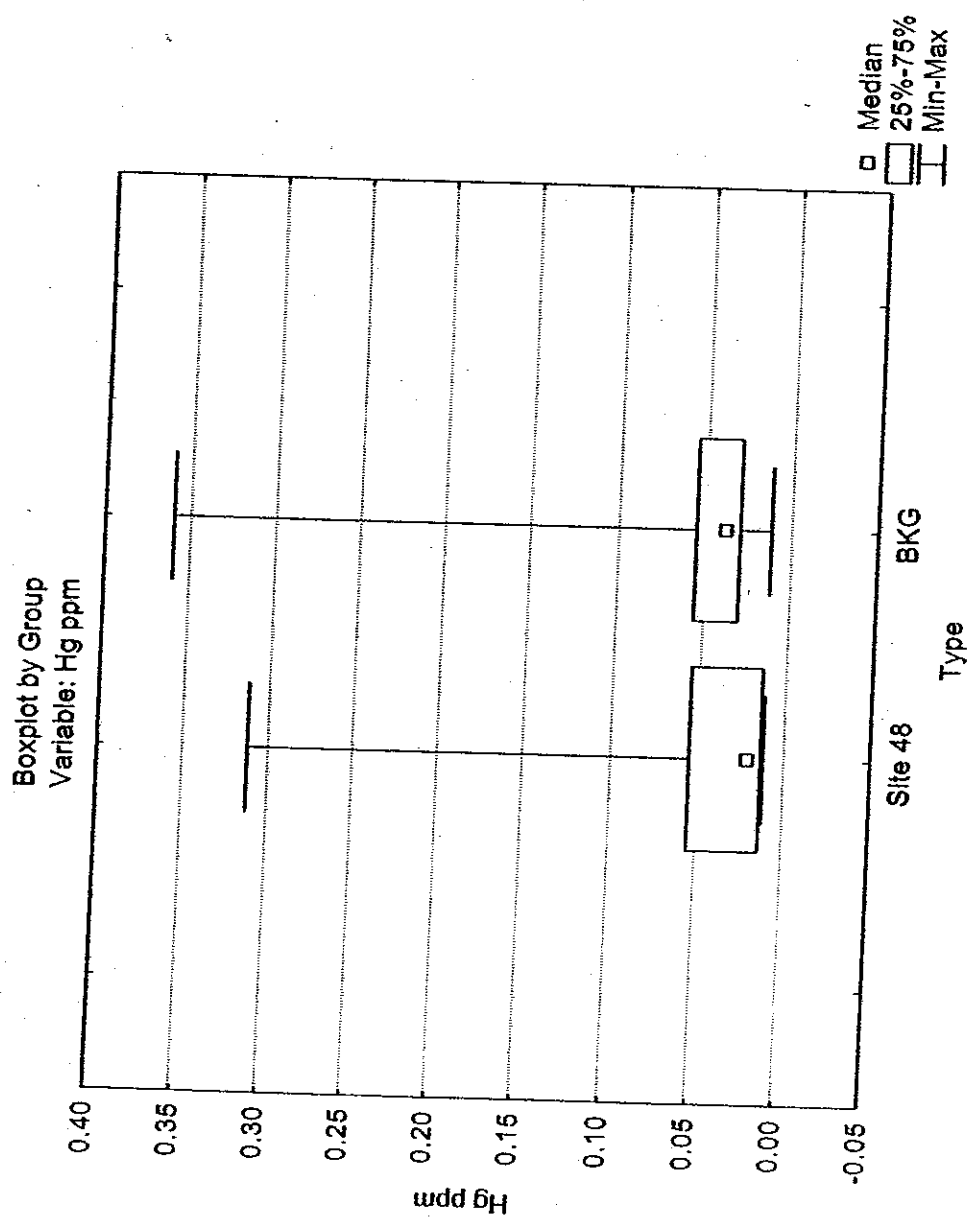






Mann-Whitney U Test (Sheet1 in LHAAP48Soll.stw)										
By variable Type										
Marked tests are significant at p < .05000										
variable	Rank Sum Site 48	Rank Sum BKG	U	Z	p-level	Z adjusted	p-level	Valid N Site 48	Valid N BKG	2*1sided exact p
Cd ppm	3805.000	1655.000	59.00000	8.378851	0.000000	8.381154	0.000000	48	56	0.000000





Attachment 2

***Geochemical Evaluation of Concentrations
of Metals in Soil LHAAP-48***

Geochemical Evaluation of Concentrations of Metals in Soil

LHAAP-48

Longhorn Army Ammunition Plant

1.0 Introduction

This report provides the results of a geochemical evaluation of inorganic constituents in soil samples from the LHAAP-48 site at Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. Five elements in the site data set failed statistical comparison to background, and a geochemical evaluation was performed to determine if the elevated concentrations are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluation consist of 48 soil samples collected over a five -year period from June 1993 through July 1998. The samples were obtained various from depths ranging from 0 to 12.8 feet below ground surface. All 48 samples were analyzed for the 23 target analyte list (TAL) metals (including aluminum, iron, and manganese). Installation-wide background data for TAL metals in soil are provided in the background study report (Shaw Environmental, Inc., 2004) and are used in the following evaluation.

2.0 Geochemical Evaluation Methodology

Statistical site-to-background comparisons for trace elements in soil commonly have high false-positive error rates (erroneous declarations of contamination). A large number of background samples is required to adequately characterize the upper tails of most trace element distributions, which are typically right-skewed and span a wide range of concentrations, but such a large background data set is not always feasible. Higher false-positive error rates are expected if the site sample size is greater than the background sample size. The presence of estimated concentrations and nondetects with differing reporting limits can also cause statistical comparison tests to fail.

Statistical tests consider only the absolute concentrations of individual elements, and they disregard the interdependence of element concentrations and the geochemical mechanisms controlling element behavior. However, it is well established that trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

Recent publications indicate that geochemical evaluations are assuming a larger role in environmental investigations (e.g., U.S. Environmental Protection Agency, 1995; Barclift, et al., 2000; U.S. Navy, 2002 and 2003; Myers and Thorbjornsen, 2004). A properly executed geochemical evaluation can distinguish between naturally high element concentrations versus contamination, and it can identify the specific samples that may contain some component of site-related contamination. This section describes the geochemical evaluation techniques that were employed in the LHAAP-48 soil investigation.

It should be noted that the geochemical evaluations rely in part on professional judgment. Samples that plot off the linear trend on a correlation plot are certainly suspect, but because all uncertainty cannot be eliminated from the evaluation, such plots cannot be construed as definitive proof of contamination. However, anomalous samples should be flagged as suspect, and their results should be used as a basis for further investigation, risk assessment, or remediation, as appropriate.

Geochemical evaluation of inorganic data is not a new concept, and it is based in part on the well-understood processes of trace element adsorption that are described in the literature (e.g., Gullledge and O'Connor, 1973; McKenzie, 1980; Electric Power Research Institute [EPRI], 1984; Hem, 1985; EPRI, 1986; Belzile and Tessier, 1990; Bowell, 1994; Manceau, 1995; Stumm and Morgan, 1996; Sullivan and Aller, 1996; Drever, 1997; Belzile et al., 2000; Nickson et al., 2000; Kabata-Pendias, 2001; Lai and Chen, 2001; Emmanuel and Erel, 2002; Munk et al., 2002; Roddick-Lanzilotta et al., 2002; Smedley and Kinniburgh, 2002; Cornell and Schwertmann, 2003; Welch and Stollenwerk, 2003). These papers, texts, and monographs provide the technical basis for the geochemical evaluations performed for the LHAAP project. This fundamental research has been applied in numerous peer-reviewed papers that employ correlation plots of trace elements versus specific major elements. The aims of these applied-science papers are to determine the likely mechanisms controlling element concentrations and identify potentially contaminated samples (e.g., Windom et al., 1989; Hanson et al., 1993; Daskalakis and O'Connor, 1995; Schiff and Weisberg, 1997; Barclift et al., 2000; Kuss et al., 2001; Chen et al., 2002; El Bilali et al., 2002; Mostafa et al., 2004). In many cases, these papers use the same types of analytical data that are obtained during the LHAAP investigations and typical environmental investigations at other sites.

Trace Elements in Soil Trace elements naturally associate with specific soil-forming minerals, and geochemical evaluations are predicated on these known associations. For example, in most uncontaminated oxic soils, arsenic exhibits an almost exclusive association with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). Arsenic exists in oxic soil pore fluid as oxyanions such as HAsO_4^{-2} and H_2AsO_4^- (Brookins, 1988), and these negatively charged species have a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge (EPRI, 1986). (In this report, the term “iron oxide” encompasses oxides, hydroxides,

oxyhydroxides, and hydrous oxides of iron.) This association is expressed as a positive correlation between arsenic concentrations and iron concentrations for uncontaminated samples: soil samples with a low percentage of iron oxides will contain proportionally lower arsenic concentrations, and soil samples that are enriched in iron oxides will contain proportionally higher arsenic concentrations. Although there is variability in the absolute concentrations of arsenic and iron in soil at a site, the As/Fe ratios of the samples will be relatively constant if no contamination is present (Daskalakis and O'Connor, 1995). Samples that contain excess arsenic from a contaminant source (e.g., an arsenic-bearing herbicide) will exhibit anomalously high As/Fe ratios compared to the uncontaminated samples.

To perform the geochemical evaluation, correlation plots are constructed to explore the elemental associations and identify potentially contaminated samples. The detected concentrations of the trace element of interest (dependent variable) are plotted against the detected concentrations of the reference element (independent variable), which represents the mineral to which the trace element may be adsorbed. In the case of arsenic, the arsenic concentrations for a given set of samples would be plotted on the y-axis, and the corresponding iron concentrations would be plotted on the x-axis. If no contamination is present, then the samples will exhibit a generally linear trend, and the samples with the highest arsenic concentrations will lie on this trend. This result indicates that the elevated arsenic is due to the preferential enrichment of iron oxides in those samples and that the arsenic has a natural source. If, however, the samples with high arsenic concentrations have low or moderate iron concentrations (anomalously high As/Fe ratios), then they will lie above the linear trend established by the other samples. This would indicate that the anomalous samples contain excess arsenic beyond that which can be explained by the natural iron oxide content, and such samples may contain a component of contamination.

The reference elements against which trace elements are evaluated reflect the affinity that the trace elements have for specific minerals. The concentrations of iron, aluminum, and manganese serve as qualitative indicators of the amounts of iron oxide, clay, and manganese oxide minerals in the soil samples. Along with arsenic, selenium and vanadium are present in oxic soil pore fluid as anions and have an affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Concentrations of arsenic, selenium, or vanadium in a set of samples can be evaluated through comparison to the corresponding iron concentrations. Barium, cadmium, lead, and zinc are typically present in soil as divalent cations and have an affinity to adsorb on clay minerals, which tend to maintain a net negative surface charge. Concentrations of barium, cadmium, lead, or zinc can be evaluated through comparison to the corresponding aluminum concentrations. Manganese oxides have a strong affinity to adsorb barium, cobalt, and lead (Kabata-Pendias, 2001), so concentrations of these elements can be compared to the

corresponding manganese concentrations, as long as there is enough manganese present in the soil to form discrete manganese oxides.

Over a limited range of concentrations, the adsorption of a trace element on a mineral surface can usually be described by a linear trend. Over a wider range of concentrations, a curved fit may be more appropriate for some trace elements. (This is why trace element adsorption is often expressed as a curve using Freundlich or Langmuir isotherms.) In this report, the elemental correlations are referred to as “linear trends,” although there may be some degree of curvature to the natural relationship.

It is important to note that some trace elements have very strong affinities for a particular type of mineral, whereas other elements will partition themselves between several minerals. For instance, vanadium has a particularly strong affinity for iron oxides, so correlation coefficients for vanadium versus iron in uncontaminated samples are usually very high, and this is expressed on a correlation plot as a highly linear trend. In contrast, chromium forms several coexisting aqueous species with different charges [$\text{Cr}(\text{OH})_2^+$, $\text{Cr}(\text{OH})_3^0$, and $\text{Cr}(\text{OH})_4^-$] that will adsorb on several different types of minerals including clays and iron oxides. This behavior will yield lower correlation coefficients for chromium versus iron or chromium versus aluminum relative to the coefficients observed for vanadium versus iron, and more scatter may be observed on the correlation plots. Some elements are more selective than others with respect to adsorption on specific mineral surfaces, and this selectivity is dependent on site-specific conditions, including soil pH, redox conditions, and concentrations of competing elements.

Ratio Plots. Site samples with a trace element present as a contaminant will exhibit anomalously high trace-versus-major element ratios compared to background trace-versus-major element ratios. These elevated ratios may not always be apparent in log-log correlation plots, especially at the upper range of concentrations. Therefore, ratio plots, which depict trace element concentrations on the y-axis and trace/major element ratios on the x-axis, are employed in conjunction with correlation plots in those cases where it is not immediately apparent which site samples have anomalously high elemental ratios on the correlation plots. The ratio plots permit easy identification of samples with anomalously high elemental ratios relative to background, and they have high resolution over the entire concentration range. The presence of an anomalously high elemental ratio is not definitive proof of site-related contamination; however, such samples are discussed in the text and, unless otherwise noted, are flagged as representing potential site-related contamination. This is a conservative approach.

It is also important to note that there is natural variability, as well as analytical uncertainty, in the elemental ratios of uncontaminated soil and sediment samples. Trace/major element ratios are calculated from two uncertain analytical results, so the resulting uncertainties in the ratios can produce some scatter in the points on a ratio plot. This is especially true when estimated (“J”-

qualified) analytical results are used. This can be seen on many of the plots that show more scatter of the points at the lower concentration range, where analytical uncertainties are higher and analytical results are reported with fewer significant figures.

On ratio plots, vertical trends should be expected only in those cases where the trace element adsorption is a linear process and where the trace element concentrations are controlled exclusively by adsorption on a given mineral type. Nonvertical trends are much more common in ratio plots, however, because adsorption processes often are not linear and because trace elements often have affinities for more than one type of sorptive surface. Nonlinear adsorption of a trace element on mineral surfaces will manifest itself as a curve rather than a straight line on a correlation plot and as a nonvertical trend on a ratio plot. In addition, the presence of competing ions in soil or sediment and differences in pH and redox conditions among the sample locations can add to the natural variability of elemental ratios.

Ratio plots may also be prepared for the major elements (e.g., aluminum versus Al/Fe ratios). However, adsorption is not the dominant process controlling major element concentrations. For example, aluminum and iron concentrations covary largely because they are controlled by the abundance of fine-grained minerals in the samples. The plots thus reflect physical effects rather than chemical effects such as adsorption. Linearity is often not observed in major-versus-major element correlation plots and associated ratio plots.

3.0 Results of the Geochemical Evaluation of Multiple Elements in Soil

This section presents the results of the geochemical evaluation of aluminum, antimony, barium, cadmium, and mercury in soil samples from LHAAP-48. Correlation plots and ratio plots are provided in **Figures 1** through **12**. **Table 1** lists the samples identified as containing anomalously high element concentrations.

Aluminum

Aluminum is the second most abundant of the 23 elements analyzed in the LHAAP-48 soil samples, with a mean concentration of 9,620 mg/kg (0.96 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Iron is the most abundant element analyzed in the site soil samples (mean concentration of 12,590 mg/kg, or 1.3 weight percent) and is dominantly present as iron oxides. Iron oxides are common soil-forming minerals, and they occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. A plot of aluminum versus iron concentrations can be used to qualitatively assess the relative abundance of these minerals in site soil (**Figure 1**). As seen in

the plot, the background samples and most of the site samples form a common linear trend with a positive slope. Most of the site samples with high aluminum concentrations also contain high iron concentrations, and they lie on the background trend. Aluminum in these samples is natural. Site sample LH-S98-01_1 lies below the linear trend and exhibits an anomalously low Al/Fe ratio relative to the other samples; however, the aluminum concentration in this sample (6,140 mg/kg) is well below the background range. Several site samples have slightly elevated Al/Fe ratios relative to background, and they lie slightly above the linear trend. These samples are most likely naturally enriched in clays relative to the background samples.

Potassium is a common component of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Clays are characterized by large surface-area-to-volume ratios and strong negative surface charges. As a result, the major cations, such as potassium, are attracted to these mineral surfaces and take part in cation exchange reactions. Positive correlations between aluminum and potassium concentrations are thus typically observed for uncontaminated soil samples. A plot of aluminum versus potassium reveals a linear trend with a positive slope for the site and background samples (**Figure 2**). The site samples with the highest aluminum concentrations also contain high potassium content, and they lie on the linear trend. This suggests a natural source for the elevated aluminum concentrations in the LHAAP-48 samples.

Antimony

Antimony has geochemical behavior similar to that of arsenic and, like arsenic, it has an affinity to adsorb on the surfaces of iron oxides. Positive correlations between antimony and iron concentrations are commonly observed in uncontaminated soil samples. A plot of detected antimony versus iron concentrations in the LHAAP-48 and background samples is provided in **Figure 3**. The three site samples with detectable antimony (LH-S95-01_3, LH-S98-01_1, and LH-S101-01_1) have the highest antimony concentrations of the two data sets (11 mg/kg, 7.96 E mg/kg, and 5.12 E mg/kg, respectively) and they lie above the background trend in **Figure 3**.

Another perspective on the data sets is provided in **Figure 4**, which depicts the antimony concentrations of the site and background samples (y-axis) versus their corresponding Sb/Fe ratios (x-axis). If a site sample contains excess antimony from a contaminant source, it will exhibit an anomalously high Sb/Fe ratio relative to background and will plot to the right of the background samples in **Figure 4**. All three site samples have Sb/Fe ratios that exceed the maximum background Sb/Fe ratio of 1.37E-04. Elevated antimony in these samples should be considered suspect (**Table 1**).

It is important to note that all of the site and background detections are estimated concentrations, and such values are highly uncertain. This uncertainty may explain why a stronger correlation is not observed in **Figure 3**. Many site samples have higher reporting limits relative to those of the

background samples (**Figure 5**), and of the available site reporting limits, 21 exceed the maximum background reporting limit of 7.3 mg/kg. Reporting limits are not available for the three site detections, but the estimated nature of these concentrations suggests that they may be below their respective reporting limits. The difference between the site and background reporting limits may explain why samples LH-S95-01_3, LH-S98-01_1, and LH-S101-01_1 have higher Sb/Fe ratios relative to background. In addition, samples LH-S98-01_1 and LH-S101-01_1 have the two highest iron concentrations of the site data set (51,800 mg/kg and 25,000 mg/kg, respectively); this suggests that these samples contain a naturally high proportion of iron oxides and, hence, a naturally high proportion of associated trace elements such as antimony. The three site antimony detections are identified as anomalously high because their Sb/Fe ratios exceed the background ratio range (**Table 1**). However, the estimated nature of two of these concentrations, the difference in site versus background reporting limits, and the presence of elevated iron in two of the samples suggest that this is a conservative assessment.

Barium

As discussed in **Section 2.0**, divalent cations such as barium (Ba^{2+}) have an affinity to adsorb on clay minerals, which tend to maintain a net negative surface charge. Positive correlations between barium and aluminum are thus commonly observed in uncontaminated samples. Most of the site and background samples form a common trend with a positive slope in a plot of barium versus aluminum (**Figure 6**). This suggests that barium in these samples is associated with clay minerals at ratios consistent with those of the background samples, and that it is natural. There are a few site samples, however, with anomalously high Ba/Al ratios relative to background; these samples lie above the linear background trend in **Figure 6**.

A plot of barium concentrations versus Ba/Al ratios reveals that most of the site samples have ratios that are within the background range (**Figure 7**). However, three site samples have Ba/Al ratios that exceed the maximum background ratio of 0.039. Elevated barium in these three samples should be considered suspect (**Table 1**).

Cadmium

Cations such as cadmium (Cd^{2+}), copper (Cu^{2+}), and nickel (Ni^{2+}) have an affinity to adsorb on the surfaces of iron oxides in the pH range of typical soils (5 to 8 standard units), with adsorption increasing as pH approaches neutrality (Cornell and Schwertmann, 2003). The cations bind to surface hydroxyl groups (OH^-), giving rise to metal-surface complexes. Because of this affinity for cation adsorption, positive correlations are commonly observed for cadmium versus iron concentrations in uncontaminated soil samples. Samples that contain a high proportion of iron oxides are therefore expected to contain naturally high concentrations of cations such as cadmium. It should be noted that cadmium detections are often low, estimated concentrations

near or below the reporting limit, and the uncertainty associated with such values contributes to the weak correlations that are sometimes observed, even for uncontaminated samples.

The background samples form a weak linear trend with a positive slope in a plot of cadmium versus iron (**Figure 8**). Most of the site samples have elevated cadmium and lie above the general background trend in **Figure 8**. Their Cd/Fe ratios exceed the maximum background Cd/Fe ratio of $1.98\text{E-}04$, but they form a linear trend with a positive slope. Most of the Cd/Fe ratios of these samples span a narrow range from $2.2\text{E-}04$ to $3.5\text{E-}04$ (**Figure 9**). These samples, which were collected in June 1993 and August 1993, have higher reporting limits than the background samples (all available site reporting limits are represented in **Figure 10**, along with the background reporting limits). Available site reporting limits for the 1993 sampling events range from 2.4 to 3.16 mg/kg (mean of 2.66 mg/kg), and these values are an order of magnitude higher than the background reporting limits of 0.39 to 0.48 mg/kg (mean of 0.43 mg/kg). The higher site reporting limits likely explain the slightly higher site Cd/Fe ratios relative to background. The strong linear trend formed by most of the site samples in **Figure 8** suggests that the cadmium in those samples is associated with iron oxides at a relatively constant ratio and is natural.

Seven site samples lie above the linear site trend in **Figure 8** and have higher Cd/Fe ratios relative to the other site and background samples (**Figure 9**), which suggests that they may contain a component of contamination (**Table 1**).

Mercury

Mercury can adsorb on the surfaces of iron oxide and clay minerals, but its concentrations are commonly controlled through organic complex formation (Kabata-Pendias, 2001). As a result, poor correlations for mercury versus iron or mercury versus aluminum are often observed, even in uncontaminated soil samples. In addition, mercury concentrations are often estimated detections near or below the reporting limit, and the uncertainty associated with such values contributes to the weak correlations. A plot of mercury versus iron is provided in **Figure 11**. Most of the background samples form a weak linear trend with a positive slope. The site samples lie on or near the background trend.

Figure 12 displays the mercury concentrations of the site and background samples (y-axis) versus their corresponding Hg/Fe ratios (x-axis). If a site sample contained excess mercury from a contaminant source, it would exhibit an anomalously high Hg/Fe ratio relative to background and would plot to the right of the background samples in **Figure 12**. However, all of the site samples exhibit Hg/Fe ratios that are within the background range. This suggests a natural source for the mercury detected in the site samples. It is important to note that seven of the nine site mercury detections and all but one of the background mercury detections are estimated

concentrations, and the uncertainty associated with such values explains why a stronger correlation is not observed in **Figure 11**.

4.0 Summary

Aluminum, antimony, barium, cadmium, and mercury in the LHAAP-48 soil data set failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated site concentrations could be explained as the result of natural processes.

Geochemical evaluation indicates that all detected concentrations of aluminum and mercury in the site soil samples are naturally occurring. Anomalously high concentrations of antimony, barium, and cadmium are present in three to seven samples each (**Table 1**). These concentrations may contain a component of contamination.

5.0 References

Barclift, D., J. Heath, and A. Drucker, 2000, "Focus on Environmental Background Data Analysis," *Soil Sediment & Groundwater*, August/September, pp. 10-17.

Belzile, N., and A. Tessier, 1990, "Interactions between arsenic and iron oxyhydroxides in lacustrine sediments," *Geochimica et Cosmochimica Acta*, Vol. 54, No. 1, pp. 103-109.

Belzile, N., Y. W. Chen, and R. Xu, 2000, "Early diagenetic behavior of selenium in freshwater sediments," *Applied Geochemistry*, Vol. 15, No. 10, pp. 1439-1454.

Bowell, R. J., 1994, "Sorption of arsenic by iron oxides and oxyhydroxides in soils," *Applied Geochemistry*, Vol. 9, No. 3, pp. 279-286.

Brookins, D. G., 1988, *Eh-pH Diagrams for Geochemistry*, Springer-Verlag.

Chen, M., L. Q. Ma, and W. G. Harris, 2002, "Arsenic Concentrations in Florida Surface Soils: Influence of Soil Type and Properties," *Soil Science Society of America Journal*, Vol. 66, pp. 632-640.

Cornell, R. M. and U. Schwertmann, 2003, *The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses*, Second Edition, Wiley-VCH, Weinheim.

Daskalakis, K. D. and T. P. O'Connor, 1995, "Normalization and Elemental Sediment Contamination in the Coastal United States," *Environmental Science & Technology*, Vol. 29, No. 2, pp. 470-477.

Drever, J. I., 1997, *The Geochemistry of Natural Waters: Surface and Groundwater Environments*, Third Edition, Prentice Hall, Upper Saddle River, New Jersey.

El Bilali, L., P. E. Rasmussen, G. E. M. Hall, and D. Fortin, 2002, "Role of sediment composition in trace metal distribution in lake sediments," *Applied Geochemistry*, Vol. 17, No. 9, pp. 1171-1181.

Electric Power Research Institute (EPRI), 1984, Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume 1: A Critical Review, EPRI EA-3356, Palo Alto, California.

Electric Power Research Institute (EPRI), 1986, Speciation of Selenium and Arsenic in Natural Waters and Sediments, Volume 2: Arsenic Speciation, EPRI EA-4641, Palo Alto, California.

Emmanuel, S. and Y. Erel, 2002, "Implications from concentrations and isotopic data for Pb partitioning processes in soils," *Geochimica et Cosmochimica Acta*, Vol. 66, No. 14, pp. 2517-2527.

Gulledge, J. H. and J. T. O'Connor, 1973, "Removal of Arsenic (V) From Water by Adsorption on Aluminum and Ferric Hydroxides," *Journal of the American Water Works Association*, Vol. 65, No. 8, pp. 548-552.

Hanson, P. J., D. W. Evans, and D. R. Colby, 1993, "Assessment of Elemental Contamination in Estuarine and Coastal Environments Based on Geochemical and Statistical Modeling of Sediments," *Marine Environmental Research*, Vol. 36, No. 4, pp. 237-266.

Hem, J. D., 1985, *Study and Interpretation of the Chemical Characteristics of Natural Water*, U. S. Geological Survey, Water Supply Paper 2254, 3rd Edition.

Kabata-Pendias, A., 2001, *Trace Elements in Soils and Plants*, Third Edition, CRC Press.

Kuss, J., C.D. Garbe-Schönberg, and K. Kremling, 2001, "Rare earth elements in suspended particulate material of North Atlantic surface waters," *Geochimica et Cosmochimica Acta*, Vol. 65, No. 2, pp. 187-199.

Lai, C. H. and C. Y. Chen, 2001, "Removal of Metal Ions and Humic Acid from Water by Iron-Coated Filter Media," *Chemosphere*, Vol. 44, No. 5, pp. 1177-1184.

Manceau, A., 1995, "The mechanism of anion adsorption on iron oxides: Evidence for the bonding of arsenate tetrahedra on free (Fe(O,OH)₆ edges," *Geochimica et Cosmochimica Acta*, Vol. 59, No. 17, pp. 3647-3653.

McKenzie, R. M., 1980, "The Adsorption of Lead and Other Heavy Metals on Oxides of Manganese and Iron," *Australian Journal of Soil Research*, Vol. 18, No. 1, pp. 61-73.

Mostafa, A.R., A. O. Barakat, Y. Qian, T. L. Wade, and D. Yuan, 2004, "An Overview of Metal Pollution in the Western Harbour of Alexandria, Egypt," *Soil & Sediment Contamination*, Vol. 13, No. 3, pp. 299-311.

Munk, L., G. Faure, D. E. Pride, and J. M. Bigham, 2002, "Sorption of trace metals to an aluminum precipitate in a stream receiving acid rock-drainage; Snake River, Summit County, Colorado," *Applied Geochemistry*, Vol. 17, No. 4, pp. 421-430.

Myers, J. and K. Thorbjornsen, 2004, "Identifying Metals Contamination in Soil: A Geochemical Approach," *Soil & Sediment Contamination*, Vol. 13, No. 1, pp. 1-16.

Nickson, R. T., J. M. McArthur, P. Ravenscroft, W. G. Burgess, and K. M. Ahmed, 2000, "Mechanism of arsenic release to groundwater, Bangladesh and West Bengal," *Applied Geochemistry*, Vol. 15, No. 4, pp. 403-413.

Roddick-Lanzilotta, A. J., A. J. McQuillan, and D. Craw, 2002, "Infrared spectroscopic characterization of arsenate (V) ion adsorption from mine waters, Macraes Mine, New Zealand," *Applied Geochemistry*, Vol. 17, No. 4, pp. 445-454.

Schiff, K. and S. B. Weisberg, 1997, "Iron as a Reference Element for Determining Trace Metal Enrichment in California Coastal Shelf Sediments," in: S. Weisberg, C. Francisco, and D. Hallock (editors), *Southern California Coastal Water Research Project Annual Report 1995-96*, pp. 68-78.

Shaw Environmental, Inc., 2004, *Final Background Soil Study Report, Longhorn Army Ammunition Plant, Karnack, Texas*, Prepared for the U.S. Army Corps of Engineers, Tulsa District, July.

Smedley, P. L. and D. G. Kinniburgh, 2002, "A review of the source, behaviour, and distribution of arsenic in natural waters," *Applied Geochemistry*, Vol. 17, No. 5, pp. 517-568.

Stumm, W. and J. Morgan, 1996, *Aquatic Chemistry*, Third Edition, Wiley-Interscience, New York.

Sullivan, K. A. and R. C. Aller, 1996, "Diagenetic cycling of arsenic in Amazon shelf sediments," *Geochimica et Cosmochimica Acta*, Vol. 60, No. 9, pp. 1465-1477.

U.S. Environmental Protection Agency, 1995, ***Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites***, Office of Research and Development, EPA/540/S-96/500, December.

U.S. Navy, 2002, ***Guidance for Environmental Background Analysis, Volume I: Soil***, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

U.S. Navy, 2003, ***Guidance For Environmental Background Analysis, Volume II: Sediment***, NFESC User's Guide UG-2054-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

Welch, A. H. and K. G. Stollenwerk (editors), 2003, ***Arsenic in Ground Water: Geochemistry and Occurrence***, Kluwer Academic Publishers, Boston.

Windom, H. L., S. J. Schropp, F. D. Calder, J. D. Ryan, R. G. Smith Jr., L. C. Burney, F. G. Lewis, and C. H. Rawlinson, 1989, "Natural Trace Metal Concentrations in Estuarine and Coastal Marine Sediments of the Southeastern United States," ***Environmental Science & Technology***, Vol. 23, No. 3, pp. 314-320.

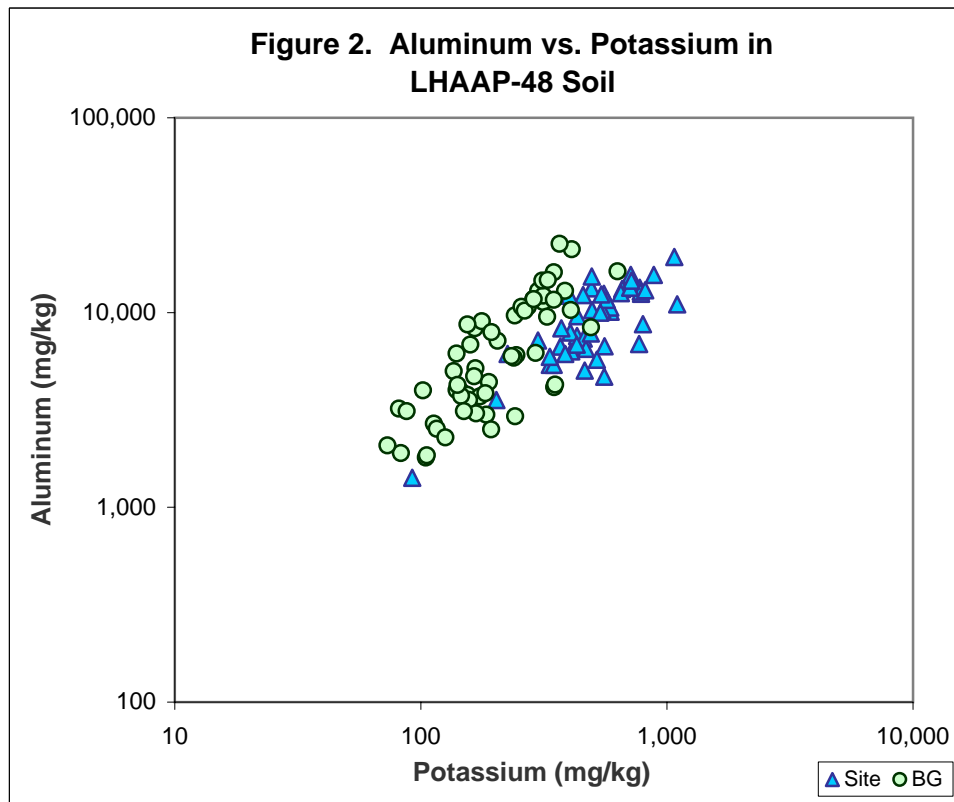
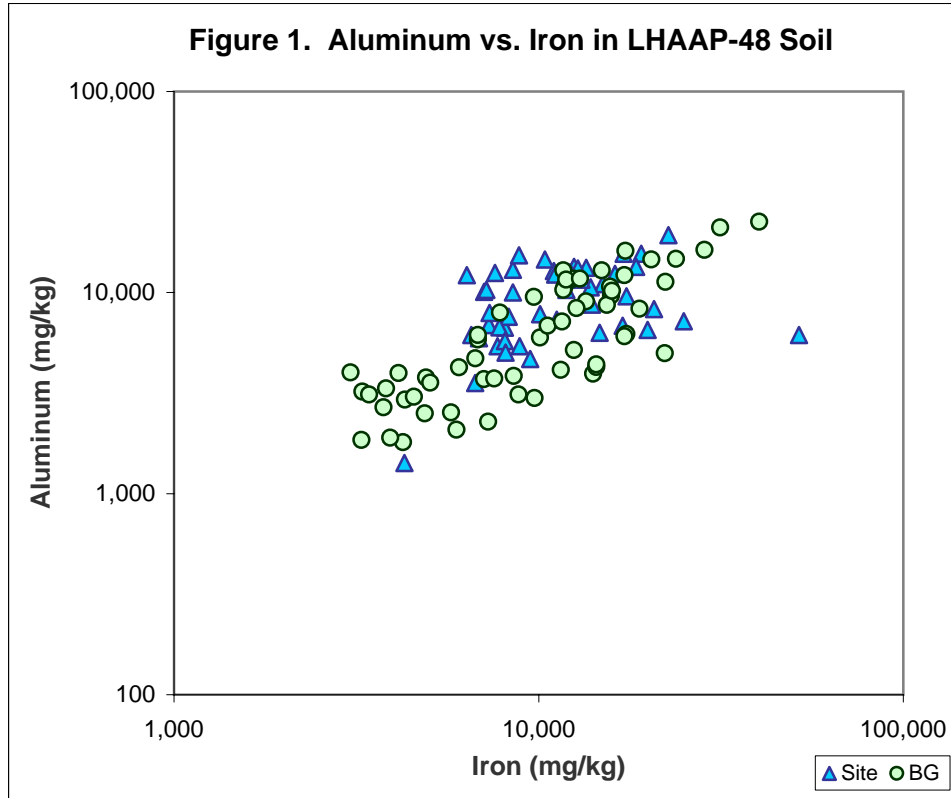
Attachment 2 Tables

Table 1
Soil Samples With Anomalously High Element Concentrations
LHAAP-48
Longhorn Army Ammunition Plant, Karnack, Texas

Location	Sample	Date	Depth	Element(s)
LH-S101-01	LH-S101-01_1	26-Jun-93	0.5 - 1.5	Antimony
LH-S101-01	LH-S101-01_2	26-Jun-93	3.8 - 4.2	Cadmium
LH-S123-01	LH-S123-01_1	26-Jun-93	0.5 - 1.5	Barium, Cadmium
LH-S123-01	LH-S123-01_2	26-Jun-93	11 - 12.5	Cadmium
LH-S94-01	LH-S94-01_1	20-Aug-93	0.5 - 1.5	Cadmium
LH-S94-01	LH-S94-01_2	20-Aug-93	2.9 - 3.5	Cadmium
LH-S95-01	LH-S95-01_1	26-Jun-93	0.5 - 1.5	Barium
LH-S95-01	LH-S95-01_3	26-Jun-93	11.3 - 12	Antimony
LH-S98-01	LH-S98-01_1	26-Jun-93	0.5 - 1.5	Antimony
LH-WRS3-01	LH-WRS3-01_1	26-Jun-93	0.5 - 1.5	Cadmium
LH-WRS3-01	LH-WRS3-01_2	26-Jun-93	3.5 - 4.3	Cadmium
LHS-Y-06	LHS-Y-06	11-Jan-95	0 - 0.5	Barium

Note: Depths represent feet below ground surface.

Attachment 2 Figures



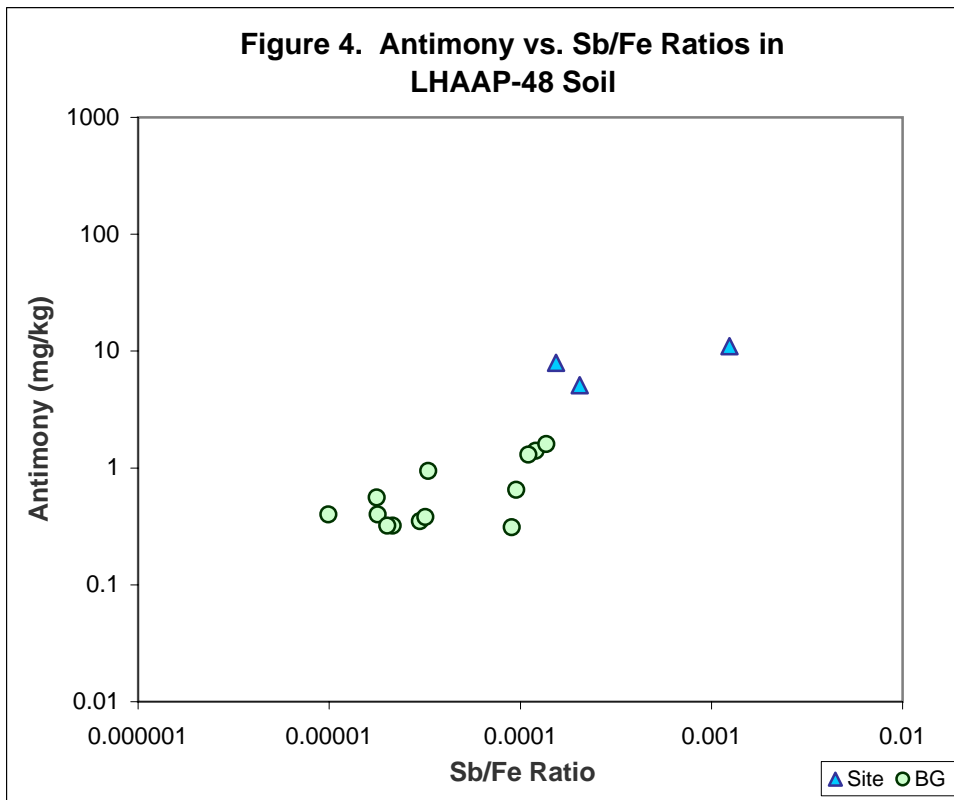
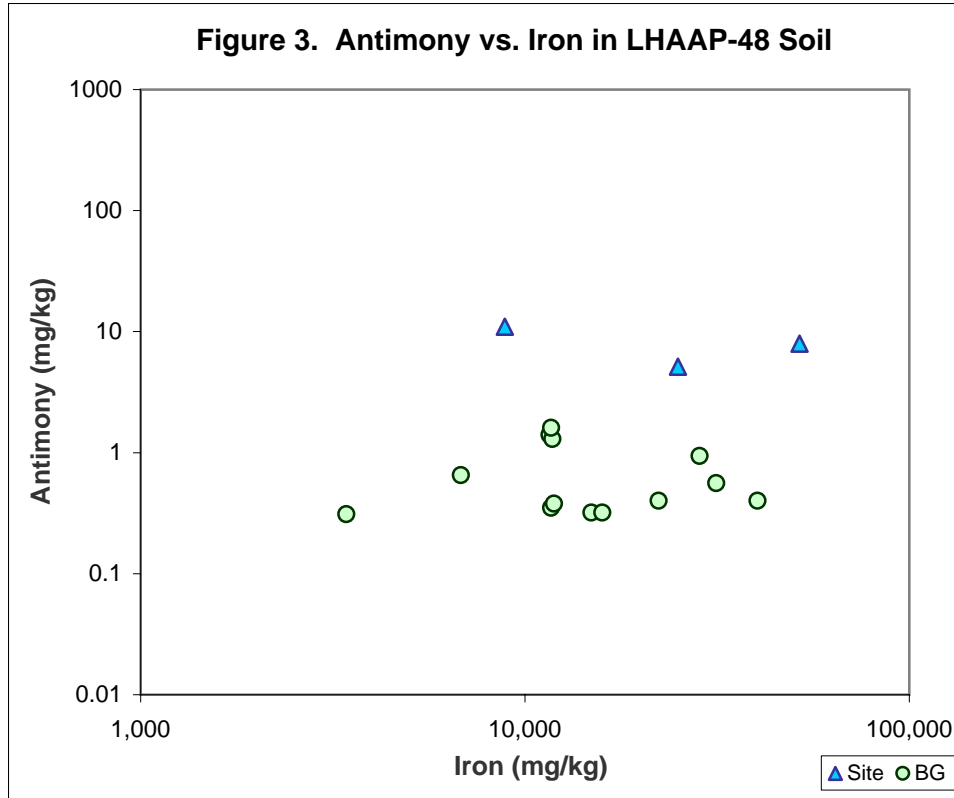


Figure 5. Histogram of Antimony Reporting Limits, LHAAP-48 Soil

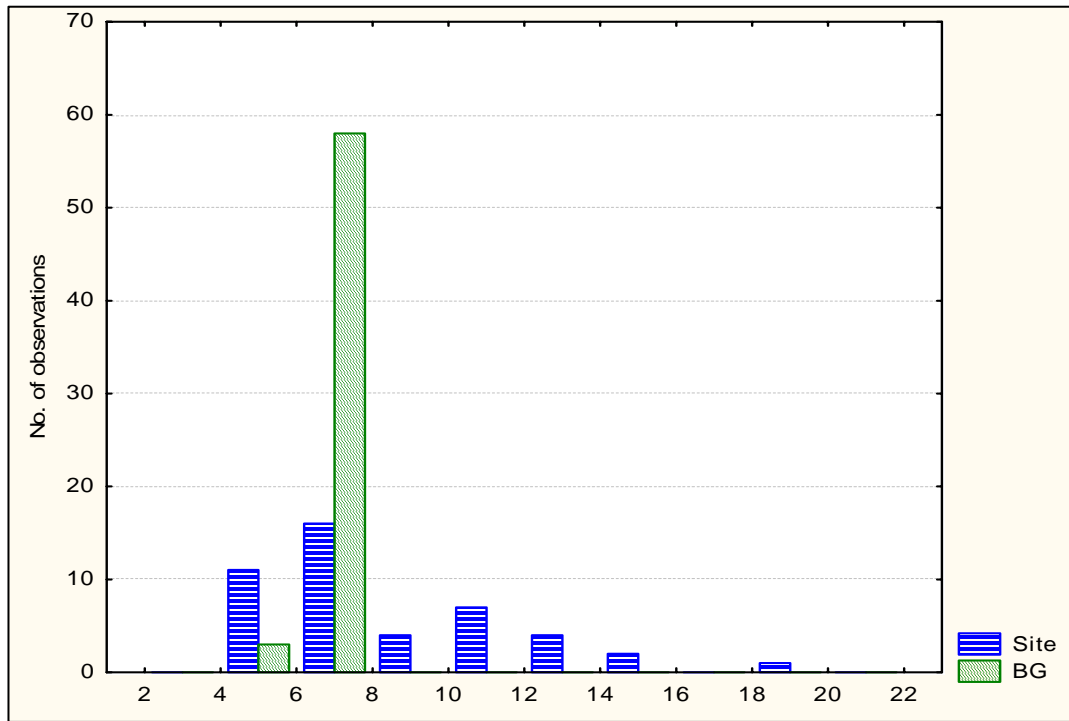
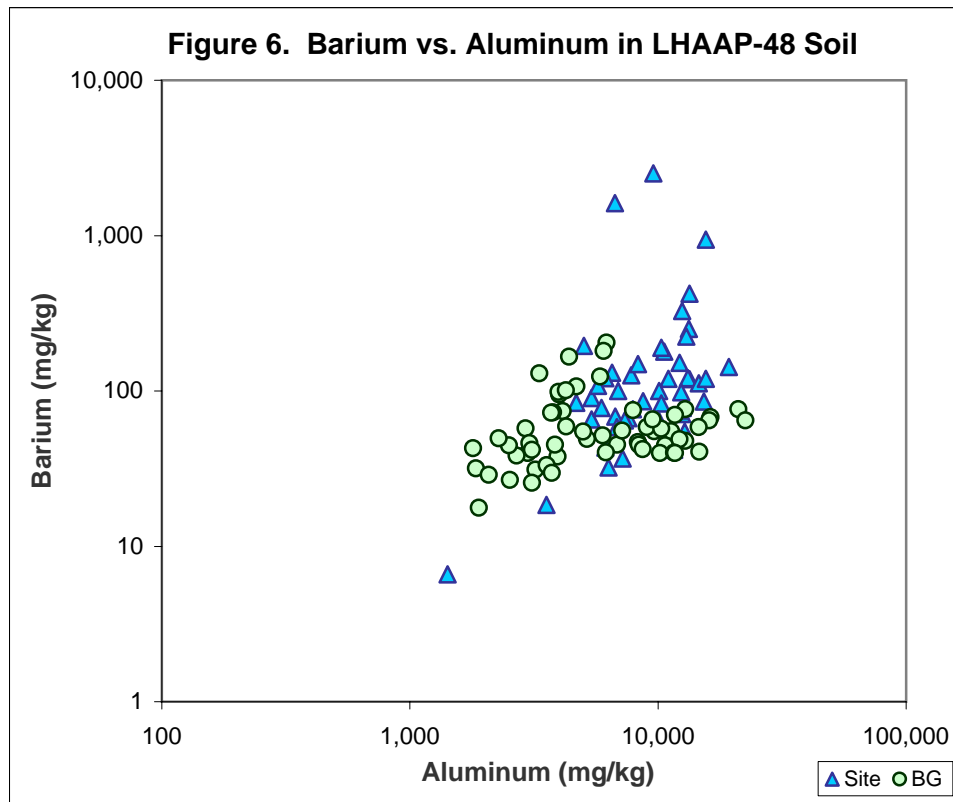
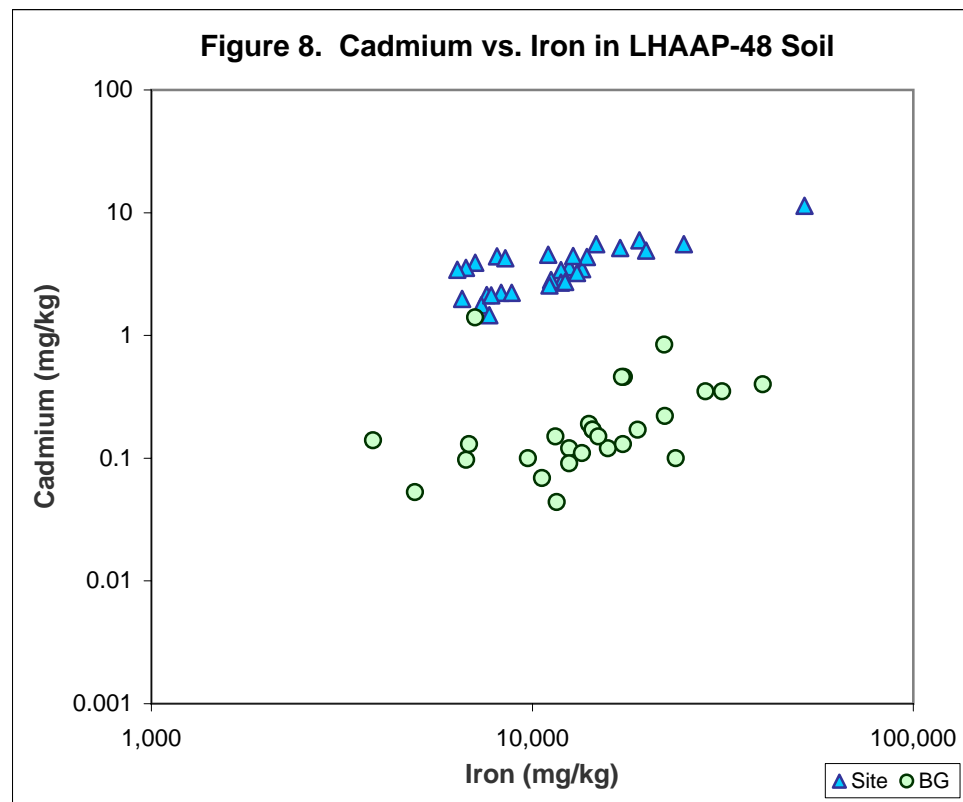
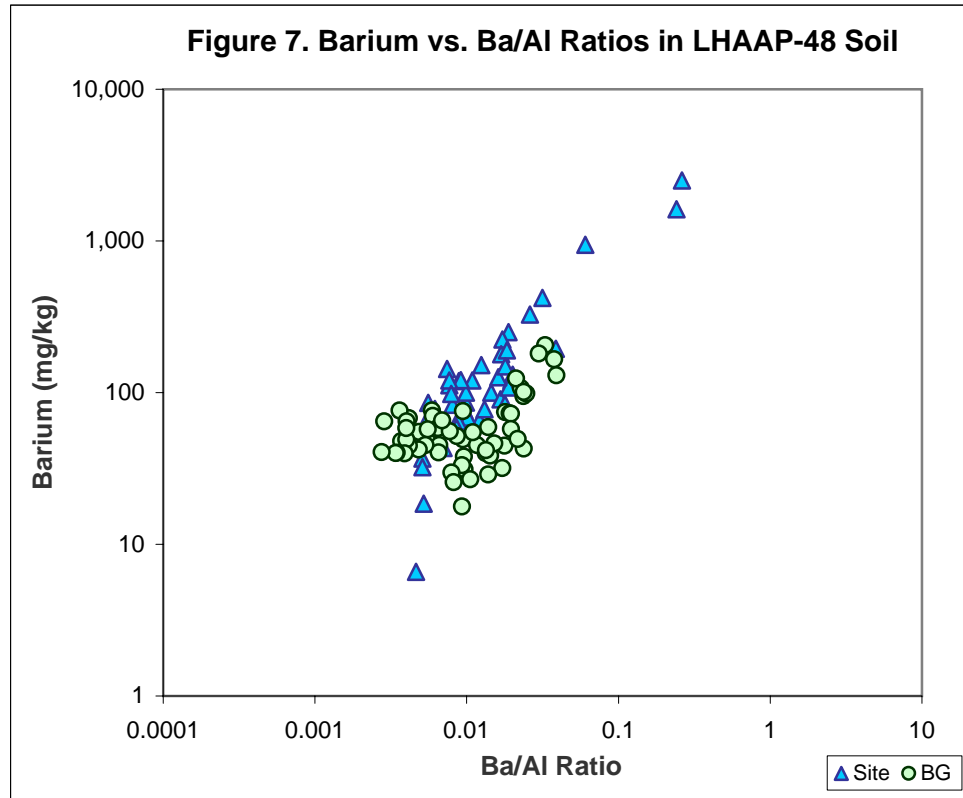


Figure 6. Barium vs. Aluminum in LHAAP-48 Soil





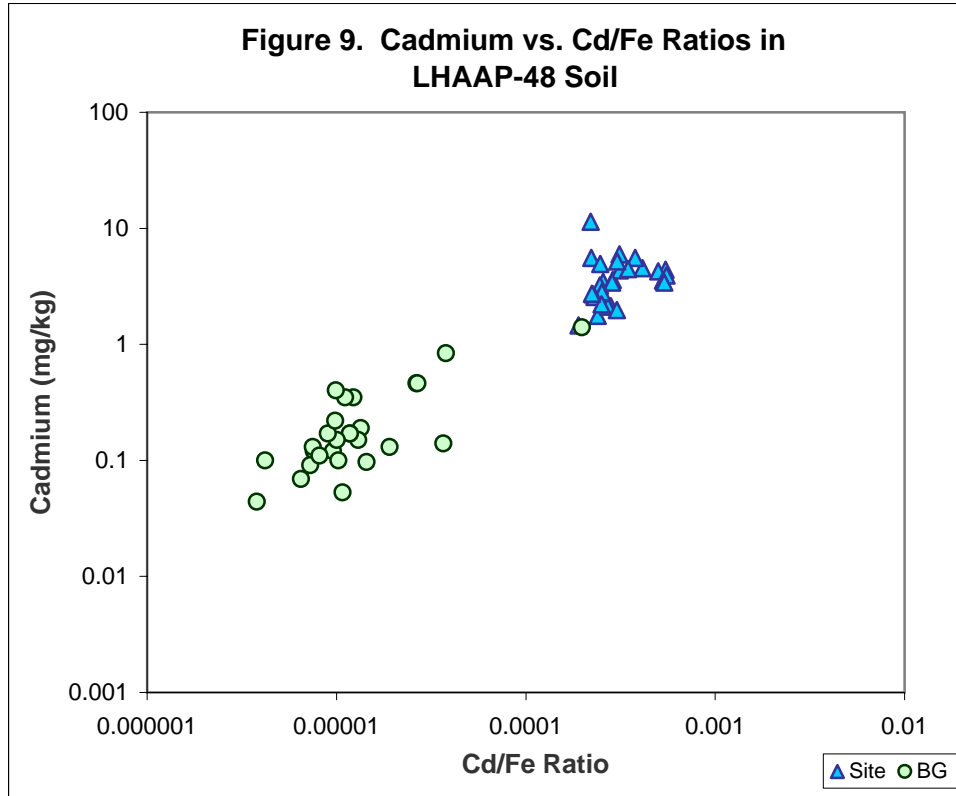
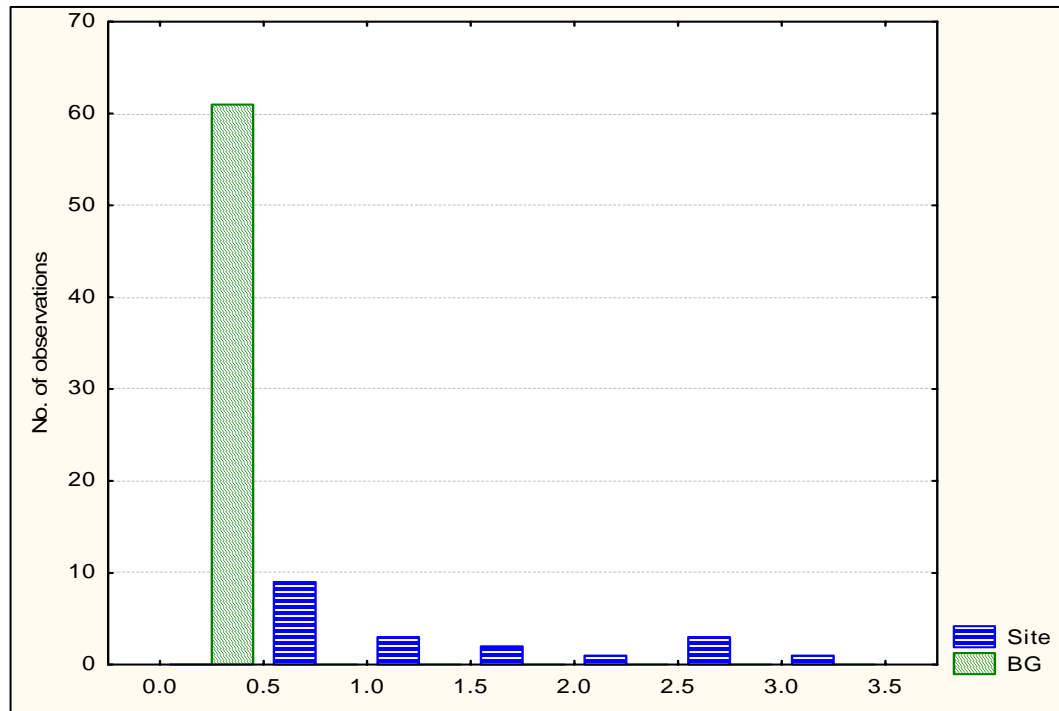
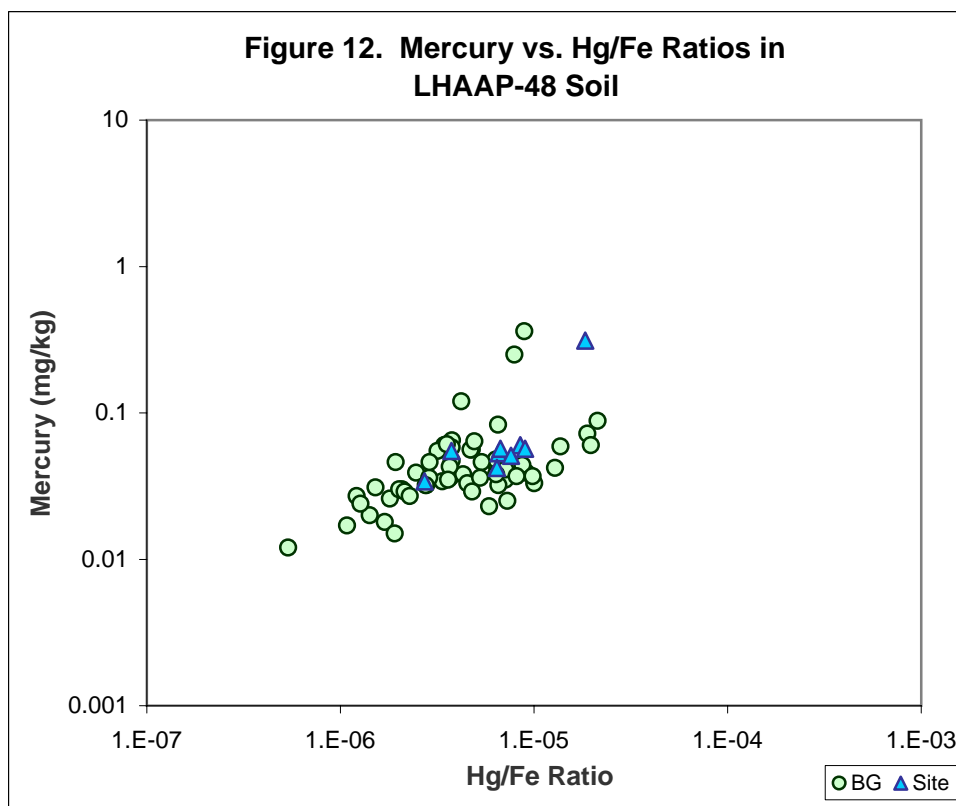


Figure 10. Histogram of Cadmium Reporting Limits, LHAAP-48 Soil





Appendix D

Baseline Risk Assessment for Residential Use of LHAAP-35C(53)

Table of Contents

List of Tables	ii
List of Figures	ii
List of Attachments	ii
Acronyms and Abbreviations	iii
1.0 Introduction	1-1
2.0 Data Evaluation.....	2-1
2.1 Evaluation of Analytical Methods.....	2-1
2.2 Summary of Sampling Efforts.....	2-1
2.3 Data Reduction.....	2-1
2.4 Evaluation of Dioxins and Furans.....	2-2
2.5 Identification of Chemicals of Potential Concern	2-3
2.5.1 Comparison of Metals to LHAAP-Specific Background Concentrations in Soil.....	2-4
2.5.1.1 Statistical Distribution Tests	2-4
2.5.1.2 Statistical Comparisons.....	2-5
2.5.1.3 Geochemical Evaluations.....	2-6
2.5.2 Organic Chemicals in Soil	2-6
2.5.3 Summary	2-6
3.0 Exposure Assessment	3-1
3.1 Land Use	3-1
3.2 Site Conceptual Model	3-1
3.3 Determination of Source-Term and Exposure-point Concentrations	3-2
3.4 Exposure Factors	3-3
3.5 Identification of Exposure Models and Assumptions	3-3
3.5.1 Ingestion Exposures to COPCs in Soil	3-3
3.5.2 Inhalation Exposures to COPCs in Soil	3-4
3.5.2.1 Volatilization Factor	3-5
3.5.3 Dermal Exposures to COPCs in Soil	3-6
4.0 Toxicity Assessment	4-1
4.1 Carcinogenic Effects.....	4-1
4.2 Noncarcinogenic Effects.....	4-2
5.0 Risk Characterization.....	5-1
5.1 Carcinogenic Effects of Chemicals.....	5-1
5.2 Noncancer Effects of Chemicals.....	5-2
5.3 Risks Associated With Exposure to Soil	5-3
6.0 Uncertainty Analysis	6-1
7.0 References	7-1

List of Tables

Table D-1	Soil Sample Summary, LHAAP-35C(53)
Table D-2	Concentrations of 2,3,7,8-TCDD Toxicity Equivalent Quotient of Dioxin and Furan Congeners in Soil at LHAAP-35C(53)
Table D-3	Surface Soil Samples, LHAAP-35C(53)
Table D-4	Exposure Factors Used to Estimate Intake of Chemicals of Potential Concern, LHAAP-35C(53)
Table D-5	Toxicity Values for Chemicals of Potential Concern, LHAAP-35C(53) Site
Table D-6a	Incremental Lifetime Cancer Risk (ILCR) for Potential Ingestion Exposure of Future Residents to Chemicals from Soil at the LHAAP-35C(53) Site
Table D-6b	Hazard Index (HI) for Potential Ingestion Exposure of Future Residents to Chemicals from Soil at the LHAAP-35C(53) Site
Table D-7a	Incremental Lifetime Cancer Risk (ILCR) for Potential Inhalation Exposure of Future Resident to Airborne Chemicals from Soil at the LHAAP-35C(53)
Table D-7b	Hazard Index (HI) for Potential Inhalation Exposure of Future Resident to Airborne Chemicals from Soil at the LHAAP-35C(53)
Table D-8a	Incremental Lifetime Cancer Risk (ILCR) for Potential Dermal Exposure of Future Residents to Chemicals from Soil at the LHAAP-35C(53)
Table D-8b	Hazard Index (HI) for Potential Dermal Exposure of Future Residents to Chemicals from Soil at the LHAAP-35C(53)
Table D-9a	Exposures and Incremental Lifetime Cancer Risks for Potential Exposure of Future Resident to Soil at the LHAAP-35C(53)
Table D-9b	Exposures and Noncancer Hazards for Potential Exposure of Future Resident to Soil at the LHAAP-35C(53)

List of Figures

Figure D-1	Sample Location Map, LHAAP-35C(53)
------------	------------------------------------

List of Attachments

Attachment 1	Statistical Comparison to Background Concentrations
Attachment 2	Geochemical Evaluation of Aluminum in Soil Samples LHAAP-35C(53)

Acronyms and Abbreviations

ABS _d	dermal absorption factor
ABS _{GI}	gastrointestinal absorption factor
atm	atmosphere
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm/sec	centimeter per second
cm ²	centimeter square
cm ³	cubic centimeters
COPCs	Chemicals of Potential Concern
CSEM	conceptual site exposure model
g	gram
IRIS	integrated risk information system
LHAAP	Longhorn Army Ammunition Plant
m	meter
MCL	maximum contaminant levels
MDC	maximum detected concentrations
µg/m ³	micrograms per cubic meter
mg/kg	milligrams per kilogram
MSSLs	medium-specific screening levels
RBSV	risk-based screening values
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
sec	second
SF	slope factor
Shaw	Shaw Environmental, Inc.
STC	source-term concentration
TCEQ	Texas Commission on Environmental Quality
TEF	toxicity equivalency factor
TEQ	toxicity equivalent quotient
UCL	upper confidence limit
UPL	upper prediction limit
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UTL	upper tolerance limit

1.0 Introduction

This residential risk assessment, prepared by Shaw Environmental, Inc. (Shaw) for the U.S. Army Corps of Engineers (USACE), Tulsa District, under Total Environmental Restoration Contract DACA56-94-D-0020, Task Order 0109, describes the risk associated with residential use of LHAAP-35C(53) located at the Longhorn Army Ammunition Plant (LHAAP) near Karnack, Texas. The results of this assessment will be used to support decisions related to residential use of LHAAP-35C(53). Environmental sampling and analysis efforts were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

The assessment of potential risk to current trespassers and future maintenance workers for exposure to chemicals in soil in a hypothetical industrial setting at LHAAP-35C(53) have been reported as acceptable (Jacobs, 2003). Estimated risk from potential groundwater ingestion by industrial workers was unacceptable and predominantly associated with thallium, silver, nickel, aluminum, and dioxins, with lesser contributions from dinitrotoluene and dichloroethane. Chromium, lead, thallium, and trichloroethene exceeded their respective maximum contaminant levels (MCLs) established by the Safe Drinking Water Act (Jacobs, 2003). Experience at other sites has shown that metals and dioxin concentrations in groundwater can be elevated due to high turbidity of the sample. Because of the uncertainty of these analysis results, additional samples were taken by Shaw in 2004 and 2005 using low-flow sampling methods to ensure that samples have low turbidity (Shaw, 2004a, 2005).

The environmental data used in the industrial risk assessment (Jacobs, 2003) and groundwater gathered by Shaw in 2004 and 2005 data were evaluated to supplement the industrial risk assessment and provide risk managers with information about the suitability of the site for residential use. The evaluation of data to identify chemicals of potential concern (COPCs) in each environmental medium sampled follows guidance from the USEPA (1992a,b,c; 2002a,b) and the Texas Commission on Environmental Quality (TCEQ) (TCEQ, 1998, 2001, 2003, and 2004). Uncertainties associated with the identification of COPCs and the impact on future decisions regarding the site are described herein.

Figures and tables that support this appendix are presented at the end of the text portion. There are two attachments that follow the figures and tables: **Attachment 1, Statistical Comparison to Background Concentrations**; and **Attachment 2, Geochemical Evaluation of Aluminum in Soil Samples at LHAAP-35C(53)**.

2.0 *Data Evaluation*

The COPCs were identified by comparing the results of chemical concentrations in soil (Jacobs, 2003) with LHAAP background concentrations, risk-based screening values, and other criteria.

2.1 *Evaluation of Analytical Methods*

Soil and water samples were analyzed according to USEPA methods (USEPA, 1983, 1992a). Evaluation of analytical data reported before June 2002 was described in the industrial risk assessment (Jacobs, 2003). After June 2002, samples were collected and analyzed as described in the work plans for LHAAP sites (Shaw, 2004a,b) and in this section.

2.2 *Summary of Sampling Efforts*

Soil and groundwater samples were collected between 1993 and 2005. Because no surface water bodies are located within the LHAAP-35C(53) boundary, no surface water or sediment samples have been collected (Jacobs, 2003).

Soil samples from LHAAP-35C(53) were collected from depths less than 15 feet below ground surface (bgs) during three phases of a remedial investigation (RI) effort conducted from 1993 through 1998 (Jacobs, 2003). Soil samples were taken from 12 soil borings located adjacent to the 4 sump locations in the Phase I RI of 1993. In 1994 and 1995, the Phase II RI included installation of five monitoring wells. Four wells were installed in the shallow subsurface that range from 17.5 to 22 ft bgs, and one well (LHSMW69) was installed as an intermediate well at 51 feet bgs (Jacobs, 2003). Soil and groundwater samples were collected from these five wells at LHAAP-35C(53) in 1994 – 1995. Additional soil samples were also collected from two ditch and drainage ways during the Phase II RI (Jacobs, 2003). The Phase III RI conducted in 1998 involved completion of soil borings at each of the four sump locations. One surface and one subsurface soil sample was collected from each soil boring. Groundwater samples were collected from the seven existing monitoring wells in the Phase III RI. Two rounds of sampling were conducted at the 7 monitoring wells in 1996, as well as a perchlorate analysis of groundwater and soil in May 2000 and February 2001 (Jacobs 2003). Wells 35CWW107, LHSMW67, LHSMW68, LHSMW69, LHSMW70, and LHSMW71 at LHAAP-35C(53) (**Figure D-1**) were sampled in May 2005 and the data are included in this residential risk assessment.

2.3 *Data Reduction*

Analytical data were evaluated as follows:

- Samples with all validation qualifiers were included in the residential risk assessment except for “R”-qualified data, which were rejected from the data set
- “J”- qualified data were included as detected concentrations
- “E”- qualified data were included as detected concentrations
- “B”- qualified data were treated as non-detected concentrations
- All non-detected concentrations were assigned a value equal to half the reporting limit.

A more detailed discussion of data qualifiers and their interpretation is given in the work plan (Shaw, 2004b).

The soil samples analyzed are presented in **Table D-1**. Thirty-six soil samples from 14 locations were evaluated. Duplicates were collected for five samples for analytical quality control purposes (**Table D-1**), and the average concentration was evaluated as a single sample.

Chemicals detected in groundwater that contributed to health risk and hazard in previous assessments (Jacobs, 2003) were either not detected or below MCLs when analyzed in groundwater collected by low-flow methods (see Section 3.1 of the main text). The detection of chromium in one shallow well, which marginally exceeded the MCL concentration, appears to be associated with sediments and with well construction materials. Because these data do not provide a strong indication of risk associated with groundwater at LHAAP-35C(53), they are not considered further in the residential risk assessment (see Section 3.2 in the main text).

2.4 Evaluation of Dioxins and Furans

Dioxins and furans were evaluated using the 2,3,7,8-TCDD toxicity equivalency (TEQ) approach. Individual congener concentrations were multiplied by toxicity equivalency factors (TEF) recommended by Van den Berg et al. (1998), and then summed to describe a 2,3,7,8-TCDD TEQ concentration for each sample.

A total of 6 samples, 4 samples (including one QC sample) collected at 0 – 0.5, 1 – 3, and 3 – 5 feet at boring 35CSB01 and 2 samples collected at SUMP105 were analyzed for dioxins/furans. Results of dioxins analysis were reported in the RI (Jacobs, 2002) and are shown in **Table D-2**. The concentrations reported as not detected (U-qualified) are shown in **Table D-2** as one-half of the reporting limit given in RI report.

2.5 Identification of Chemicals of Potential Concern

The COPCs were identified as chemicals that were detected at concentrations above one or more highly conservative criteria designed to eliminate from further evaluation those chemicals that are unlikely to cause adverse effects.

The COPCs for the residential risk assessment were identified using the following criteria:

- **Essential Human Nutrients.** (Calcium, chloride, iron, magnesium, phosphorus, potassium, and sodium) were eliminated as COPCs (TCEQ, 2001, 2003).
- **Risk-Based Screening.** A risk-based screening step was used to identify chemicals that would contribute significantly to human health risk. Chemicals with maximum detected concentrations (MDC) equal to or below risk-based screening concentrations were eliminated from further evaluation. The TCEQ risk-based screening values (RBSV) were used in this step (TCEQ, 2004). The RBSVs are concentrations that are protective of human health exposure via ingestion, inhalation, and dermal absorption pathways at a 1E-06 target risk level for carcinogens and a 0.1 target hazard quotient for noncarcinogens. Where contaminants have both cancer and noncancer toxicity factors, the RBSV represents the lower (i.e., more conservative) value. The RBSVs are protective of residential land-use scenarios. When an RBSV was not available for a chemical, other sources were consulted to develop risk-based screening concentrations such as the USEPA Region 6 medium-specific screening levels (MSSLs) (USEPA, 2004).
- **Frequency of Detection.** Chemicals were eliminated as COPCs if they were detected infrequently (5 percent or lower frequency of detection) at low levels, providing that at least 20 samples were analyzed for the chemical and the chemical is not known to be associated with site operations (TCEQ, 1998; USEPA, 1989). Chemicals detected infrequently, but at high concentrations, were retained in the evaluation unless their exclusion could be justified based on site process information or historical data.
- **Comparison to Background.** Concentrations of chemicals were compared to background concentrations specific to LHAAP by statistical methods and geochemical evaluations. The geochemical evaluations serve as an independent check of the statistical comparisons.

Results of soil analysis were evaluated as described above to provide the following characteristics of the data set. Results are shown in **Table D-3**, which include:

- Number of samples, number of detects, number of non-detects, frequency of detection
- Minimum and maximum reporting limits
- Minimum and maximum detected values

- Mean, median, and standard deviation, as appropriate for the distribution
- 95 percent upper confidence limit (95%UCL) of the mean or median, as appropriate for the distribution
- 95 percent upper tolerance limit with 95 percent confidence (95%/95% UTL)
- 95 percent upper prediction limit (95%UPL).

The COPCs were identified as chemicals that were detected at concentrations above one or more highly conservative criteria designed to eliminate from further evaluation those chemicals that are unlikely to cause adverse effects.

2.5.1 Comparison of Metals to LHAAP-Specific Background Concentrations in Soil

A comparison to site-specific background concentrations was used to determine whether detected chemicals were related to LHAAP operations. The LHAAP-specific background concentrations for soil were developed using data that represent background concentrations for soil (Shaw, 2004c).

Concentrations of metals in soil samples shown to have at least one value that exceeds human health and ecological screening values were compared with LHAAP-specific background concentrations according to statistical methods described in USEPA (2002a) guidance.

2.5.1.1 Statistical Distribution Tests

The Shapiro-Wilk test was performed using USEPA (2002a) guidance to determine the statistical distribution of the data and to ensure that the assumptions inherent in later statistical calculations are valid. The Shapiro-Wilk test was also used to determine the distribution type of background data (Shaw, 2004c). These distribution tests were made to determine whether the normal or lognormal distribution, or a nonparametric distribution, could be used in comparisons with background data.

The Shapiro-Wilk test calculates the statistic W to test the null hypothesis H_0 : that the population has a normal distribution versus the alternate hypothesis H_A : that the population does not have a normal distribution. When applied to the logarithms of data values, the lognormality of the distribution is tested.

Two 95%UPL of background concentrations were used to screen the upper tail of the background concentration. The 95% UPL value represents the concentration that will be above the next single measurement with 95 percent confidence. The 95% UPL of the background concentration (**Table D-3**) was calculated as follows. If the background data followed either the normal or lognormal distribution the 95% UPL was calculated according to the equation (USEPA, 1992b):

$$UPL_{0.95} = X + t_{n-1,0.95} \times S \times (1+1/n)^{1/2} \quad \text{Equation D-1}$$

where:

$UPL_{0.95}$	=	the 95% UPL
X	=	mean background concentration
$t_{n-1,0.95}$	=	Student's t value for n-1 degrees of freedom and 95 percent confidence
S	=	standard deviation of the mean
n	=	number of samples

If the data were shown to be both normally and lognormally distributed, the distribution having the higher p value above 0.05 was used for the 95% UPL calculation. If the data were lognormally distributed, the 95% UPL value shown in **Table D-2** is the antilogarithm of the value calculated by **Equation D-1**.

Nonparametric methods were used if the data do not follow either the normal or lognormal distribution. The 95% UPL concentration was determined by ranking the data from highest to lowest and calculating the 95th percentile rank according to the equation:

$$UPL_{0.95} = 95^{\text{th}} \text{ percentile} = 0.95(n+1) \quad \text{Equation D-2}$$

where:

$UPL_{0.95}$	=	concentration occupying the 95 th percentile rank
95 th percentile	=	the 95 th percentile rank of the of the data set
n	=	number of samples

This 95th percentile is the same as the 95% UPL according to the assumptions made in Equation D-1.

Comparison of MDC concentrations to RBSV values and to background screening concentrations represented by the 95% UPL values indicates that mercury exceeds both the RBSV and background, and aluminum may exceed background levels (**Table D-3**). Therefore, mercury is identified as a COPC in soil for hypothetical residential use of LHAAP-35C(53).

2.5.1.2 Statistical Comparisons

Because the screening of aluminum concentrations is equivocal, aluminum was evaluated by direct statistical comparison to background data (USEPA, 2002a). The aluminum concentrations in LHAAP-35C(53) samples have a nonparametric distribution. Therefore, the data were compared using the Wilcoxon Rank Sum test (USEPA, 2002a), which tests for differences in

median concentrations. Statistical tests were made using the Statistica[®] software package (StatSoft, 1997) at the 95 percent confidence level. The results of statistical comparisons for aluminum (**Attachment 1**) indicate aluminum concentrations in soil occur above background levels at LHAAP-35C(53).

2.5.1.3 Geochemical Evaluations

The aluminum concentrations are highly variable. Because natural background concentrations are inherently variable and span a wide range of concentrations, statistical evaluations alone (especially those based on univariate statistics) sometimes lead to misleading and high background concentrations. Therefore, a geochemical evaluation of data was used as an independent check of statistical conclusions.

Geochemical evaluations examine ratios of concentrations of selected metals to confirm that the samples have the expected geochemical relationships. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples. When properly evaluated, geochemistry can provide mechanistic explanations for the observed variability in yet naturally occurring metal concentrations and provide an independent check on purely statistical evaluations.

The results of geochemical evaluations indicate that aluminum concentrations are consistent with background concentrations (**Attachment 2**).

2.5.2 Organic Chemicals in Soil

Dioxins (as 2,3,7,8-tetrachloro-p-dibenzo dioxin, TCDD toxicity equivalent), were detected at concentrations above the screening criteria (**Table D-3**). Dioxins may be associated with combustion product from testing of illumination devices and rocket motors. Therefore, dioxins are conservatively identified as the COPC in soil for hypothetical residential use of LHAAP-35C(53).

2.5.3 Summary

Table D-3 illustrates the COPC screening process for surface soil based on comparison to conservative screening values, comparison with background concentrations, and weight of evidence criteria. Mercury was identified as a COPC in soil at the LHS-MW67 boring. Dioxins were associated with Sump 105 and soil boring 48SB01.

3.0 *Exposure Assessment*

An exposure assessment estimates the type and magnitude of potential exposure of receptors to COPCs associated with a site according to the following steps (USEPA, 1989):

- Description of land and water uses
- Identification of potential receptors and exposure scenarios
- Identification of exposure pathways in a conceptual site exposure model
- Estimation of source concentrations and exposure point concentrations for COPCs
- Estimation of COPC intake rates for each exposure pathway

3.1 *Land Use*

The LHAAP-35C(53) site, also known as the Static Test Area, has an area of approximately 26 acres, and is located in the east-central portion of LHAAP at the intersections of Tyler, Tucson, and Truman Avenues. Surface features include asphalt roads and parking areas. The perimeter of LHAAP-35C(53) consists of Central Creek to the northwest and Harrison Bayou to the southeast. Runoff flows toward Harrison Bayou and on to Caddo Lake (Plexus, 2005). Transport by surface water runoff and discharge of shallow groundwater to other surface water bodies is evaluated in a separate report (Shaw, 2006).

The surface soils are clays and silty clays to approximately 12 feet bgs. A relatively thin (two- to three-foot-thick) sand layer that is continuous across the site is below the silty clay. The sand layer is the top of the shallow saturated zone in this area. The silty clay confining layer below the shallow saturated zone is not present at this location. Silty sand and clayey sand layers exist below the surficial clayey layer at 11 feet and continue to a depth of 51 feet bgs.

The hydraulic conductivity in the shallow zone was estimated at $2.8\text{E-}4$ centimeters per second (cm/sec) to the south of the site and at $1.1\text{E-}3$ cm/sec in the northeastern portion of the site near Harrison Bayou. The groundwater flow direction in the shallow zone is to the north. (Jacobs, 2002).

This assessment assumes hypothetical residential use of the LHAAP-35C(53) site as described above and as discussed by the analytical data (**Table D-3**).

3.2 *Site Conceptual Model*

The exposure assessment for soil at LHAAP-35C(53) incorporates a conceptual site exposure model (CSEM) to provide the basis for identifying and evaluating the potential risks to a hypothetical resident and helps verify that exposures are not overlooked. The elements of a CSEM include:

- Source of affected media
- Chemical release mechanisms
- Chemical transport pathways
- Transport media
- Exposure media
- Receptors
- Exposure pathways

The CSEM developed for the LHAAP-35C(53) residential land-use scenario assessment is the same model developed for the current trespasser and future on-site worker (Figure 3-2 of Jacobs, 2003) with the following exceptions:

- The resident will be exposed to mercury and dioxins in soil by incidental ingestion, inhalation of airborne vapor and dust, and direct dermal contact.
- Exposure of the resident to dioxins in fish is not assessed. Because available surface water sources at LHAAP-35C(53) do not support a fish population, and a potential resident would have ready access to fish from Caddo Lake or one of the other watersheds, potential risk from ingestion of fish from the unnamed creek would represent the trespasser scenario evaluated in previous risk assessments (Jacobs, 2002, 2003). Therefore, the potential ingestion of fish from this ditch is not evaluated in this risk assessment.

3.3 Determination of Source-Term and Exposure-point Concentrations

The source-term concentration (STC) is the single concentration of a chemical that is representative of the environmental medium. Ideally, the STC should be the average concentration to which a receptor is exposed; i.e., the average calculated using all the samples taken from within a receptor's exposure area. Generally, the 95% UCL on the arithmetic mean is estimated to account for uncertainty regarding adequacy of the sampling.

Information for chemicals analyzed in soil is summarized in **Table D-3**, which includes:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of laboratory reporting limit concentrations
- Type of statistical distribution of concentrations
- Arithmetic mean of site concentrations
- UCL on the arithmetic mean concentration
- Background screening concentration (Shaw 2004c)
- The Texas RBSV concentration
- The 95% UPL concentration

- Identification of COPCs with the rationale for selection or rejection of a chemical as a COPC
- Source-term concentration used in the exposure assessment.

Because fewer than 10 samples were available for dioxin analysis, and mercury was detected in only 1 of 32 samples, a 95% UCL concentration could not be determined by bootstrapping methods (USEPA, 2002b). Therefore, the maximum mercury and 2,3,7,8-tetrachloro-p-dibenzo dioxin, TCDD toxicity equivalent concentrations were used as the conservative STCs for this risk assessment.

The maximum detected concentration of mercury and dioxins (**Table D-3**) was the exposure-point concentration used in exposure assessments of direct soil ingestion and dermal contact pathways. Exposures by the indirect pathway, to airborne dust, were assessed using an estimated air concentration derived from the measured soil concentration as described in **Section 3.5.2**.

3.4 Exposure Factors

This assessment is limited to the residential use of LHAAP-35C(53). Assessments of maintenance workers and trespassers on LHAAP-35C(53) were evaluated previously (Jacobs, 2003). If the LHAAP-35C(53) resident visits other LHAAP sites or watersheds (Central Creek, Goose Prairie Creek, Harrison Bayou, or Saunders Branch), those exposures are assumed to equal the trespasser scenario assessments reported for those sites (Jacobs, 2003).

The exposure factors used in the residential intake models are compiled in **Table D-4** (TCEQ, 1998; USEPA, 1989).

3.5 Identification of Exposure Models and Assumptions

The models used to quantify doses or intakes of the COPC by the identified exposure pathways were taken or modified from USEPA (1989) guidance and TCEQ (1998) guidance.

3.5.1 Ingestion Exposures to COPCs in Soil

The ingestion intake of carcinogenic COPCs in soil was estimated for children and adults according to the equation:

$$I_s = \frac{(C_s)(IF_{adj})(EF)(CF)}{(AT_c)}$$

Equation D-3

where:

I_s	=	ingestion intake of COPC in soil (mg/kg-day, calculated)
C_s	=	concentration of COPC in soil (mg/kg)

IF _{adj}	=	age-adjusted ingestion rate of soil (mg-year/kg-day)
EF	=	exposure frequency (days/year)
CF	=	conversion factor (1E-6 kg/mg)
ATc	=	averaging time for carcinogens (days; = 70 years × 365 days/year).

The ingestion intake of noncarcinogenic COPCs in soil was calculated according to the equation:

$$I_s = \frac{(C_s)(IR_{sadj})(EF)(CF)}{(AT)} \quad \text{Equation D-4}$$

where:

I _s	=	ingestion intake of COPC in soil (mg/kg-day, calculated)
C _s	=	concentration of COPC in soil (mg/kg)
IR _{sadj}	=	age-adjusted ingestion rate of soil (mg-year/kg-day)
EF	=	exposure frequency (days/year)
CF	=	conversion factor (1E-6 kg/mg)
AT	=	averaging time for exposure to noncarcinogen (days; = 30 years × 365 days/year).

3.5.2 Inhalation Exposures to COPCs in Soil

The inhalation intake of carcinogenic COPCs in airborne vapor and dust suspended from soil is estimated from the equation:

$$C_a = \frac{(C_s)(CF)(EF)(ED)(1/VF + 1/PEF)}{(AT_c)} \quad \text{Equation D-5}$$

where:

C _a	=	concentration of COPC in airborne dust (µg/m ³)
C _s	=	concentration of COPC in soil (mg/kg)
CF	=	conversion factor (1E3 µg/mg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)

- VF = volatilization factor (m^3/kg), chemical specific value calculated as described below
- PEF = particulate emission factor ($4.63 \times 10^9 \text{ m}^3/\text{kg}$, TCEQ, 1998)
- ATc = averaging time for carcinogens (days; = 70 years x 365 days/year).

The inhalation intake of airborne noncarcinogenic COPCs was calculated according to the equation:

$$C_a = \frac{(C_s)(EF)(ED)(1/VF + 1/PEF)}{(AT)} \quad \text{Equation D-6}$$

where:

- C_a = concentration of COPC in airborne dust (mg/m^3)
- C_s = concentration of COPC in soil (mg/kg)
- EF = exposure frequency (days/year)
- ED = exposure duration (year)
- AT = averaging time for exposure to noncarcinogens (days)
- PEF = particulate emission factor ($4.63 \times 10^9 \text{ m}^3/\text{kg}$, TCEQ, 1998).

3.5.2.1 Volatilization Factor

The volatilization factor for the dioxin vapor inhalation assessment was calculated using the following equation (TCEQ, 1998):

$$VF = \frac{(LS \cdot V \cdot DH)}{A} \times \frac{[3.14 \cdot a \cdot T]^{1/2}}{2 \cdot D_{et} \cdot E \cdot K_{as}} \times 10^{-3} \text{ kg} / \text{g} \quad \text{Equation D-7}$$

and:

$$\alpha = \frac{D_{ei} \cdot E}{E + (p_s \cdot I - E) / K_{as}} \quad \text{Equation D-8}$$

$$K_{as} = (H / K_d) 41 \quad \text{Equation D-9}$$

where:

LS	=	the length of contaminated area (2500 feet, 762 m from southwest boundary to Cook Rd. near LHSMW71 location (Figure D-1))
V	=	wind speed in mixing zone (2.25 m/sec, TCEQ, 1998)
DH	=	diffusion height (2 m, TCEQ, 1998)
A	=	area of contamination, 26 acres (4.05E+7 cm ²)
T	=	exposure interval (sec, TCEQ, 1998)
D _{ei}	=	effective diffusivity (cm ² /s); equal to [(D _i)(E ^{0.33})], where D _i is the chemical specific molecular diffusivity in air (cm ² /s)
E	=	default soil porosity (unitless, 0.35, TCEQ, 1998)
p _s	=	soil or particulate density (2.65 g/cm ³ , TCEQ, 1998)
K _{as}	=	soil to air partition coefficient (g soil/cm ³ air)
H	=	chemical specific Henry's Law constant (atm-m ³ /mol)
K _d	=	chemical specific soil to water partition coefficient (cm ³ /g, K _d = K _{oc} x f _{oc})
K _{oc}	=	organic carbon partition coefficient (cm ³ /g)
f _{oc}	=	fraction soil organic carbon content, (0.02, TCEQ, 1998).

3.5.3 Dermal Exposures to COPCs in Soil

Unlike the methods for estimating ingested intake of COPC, which quantify an administered dose, dermal dose is estimated as the dose that crosses the skin and is absorbed. For this reason, dermal toxicity values are also based on absorbed dose.

The absorbed dose of carcinogenic COPCs through contact with soil was estimated from the equation:

$$DAD = \frac{(C_s)(MCF)(DFadj)(ABSd)(EF)}{(ATc)} \quad \text{Equation D-10}$$

where:

DAD	=	average dermally absorbed dose of COPC from soil exposure (mg/kg-day, calculated)
C _s	=	concentration of COPC in soil (mg/kg)
MCF	=	mass conversion factor (1E-6 kg/mg)
DFadj	=	age-adjusted dermal absorption factor (mg-yr/kg-day)
ABSd	=	dermal absorption fraction of specific chemical (unitless)
EF	=	exposure frequency (days/year)
ATc	=	averaging time for carcinogens (days; = 70 years x 365 days/year).

Because a dermal absorption factor (ABSd) value for 2,3,7,8-TCDD TEQ dioxin is not provided in TCEQ (1998) guidance, the ABSd value provided for 2,3,7,8-TCDD TEQ dioxin in TCEQ (2005) guidance was used in the dermal assessment.

The dermal absorbed doses of noncarcinogenic COPCs in soil are usually calculated separately for children and adults according to the equation:

$$DAD = \frac{(C_s)(MCF)(ED)(EF)(SA)(AF)(ABSd)}{(BW)(AT)} \quad \text{Equation D-11}$$

where:

DAD	=	average dermally absorbed dose of COPC to the child or the adult from exposure to soil (mg/kg-day, calculated)
MCF	=	conversion factor (1E-6 kg/mg)
ED	=	exposure duration; (6 years for child, 24 years for adult)
EF	=	exposure frequency (days/year)
SA	=	surface area of exposed skin (2200 cm ² for child, 2500 cm ² for adult)
AF	=	adherence factor of soil to skin; (0.2 mg/cm ² -day for both child and adult receptors)

ABSd	=	dermal absorption fraction of chemical (unitless value same for both child and adult receptors)
BW	=	body weight: (15 kg for child, 70 kg for adult)
AT	=	averaging time for noncarcinogens (days; = 6 years x 365 days/year for child, 24 years x 365 days/year for adult).

Because the surface area of skin exposed for the adult receptor is slightly higher than that of the child, the dermal DAD calculated for the adult is slightly higher than the child's DAD by a factor of $2500 \text{ cm}^2 / 2200 \text{ cm}^2$, or approximately 14%. However, this slightly greater adult exposure is more than offset by the lower body weight of the child, such that the DAD calculated for the child exceeds that of the adult by a factor of $70 \text{ kg} / 15 \text{ kg}$, or approximately 460%. Therefore, the exposures calculated for the child are protective of the adult.

4.0 Toxicity Assessment

The toxicity assessment identifies the cancer and noncancer effects that may arise from exposure of humans to the COPC and provides an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects. The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described in the following sections.

4.1 Carcinogenic Effects

The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (USEPA, 1989). The qualitative aspect is a weight-of-evidence evaluation of the likelihood that a chemical might induce cancer in humans. The USEPA recognizes six weight-of-evidence group classifications for carcinogenicity:

- Group A - Human Carcinogen: human data are sufficient to identify the chemical as a human carcinogen
- Group B1 - Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed
- Group B2 - Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association
- Group C - Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation
- Group D - Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate
- Group E - Evidence of Noncarcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer

The toxicity value for carcinogenicity, the cancer slope factor (SF), is an estimate of potency. Potency estimates are developed only for chemicals in Groups A, B1, B2 and C, and only if the data are sufficient. The potency estimates are statistically derived from the dose-response curve from the best human or animal study or studies of the chemical. The cancer risk factor for inhaled carcinogens is the unit risk factor (URF) and also represents an estimate of cancer potency when applied to the airborne carcinogen concentration to which the person is exposed.

The SF is usually expressed as “extra risk” per unit of intake or exposure; that is, the additional risk above the incidence in an unexposed population. The SF is expressed as risk per mg/kg-day. The URF is expressed as risk per $\mu\text{g}/\text{m}^3$. To be appropriately conservative, the SF (or URF) is

usually the 95 percent upper bound on the slope of the dose-response curve extrapolated from high (experimental) doses to the low-dose range expected in environmental exposure scenarios. The USEPA (1989) assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk.

4.2 *Noncarcinogenic Effects*

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (USEPA, 1989) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical; these may differ depending on the duration (e.g., acute or chronic) or route (e.g., oral or inhalation) of exposure
- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased)
- Estimation of the threshold dose for the critical effect for each duration of exposure
- Development of an uncertainty factor; i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of the critical effect, slope of the dose-response curve, and deficiencies in the data base in regard to developing a reference dose (RfD) for human exposure.
- Identification of the target organ for the critical effect for each route of exposure.

This information is used to derive the reference dose, RfD, which is an exposure route- and duration-specific toxicity value expressed as mg/kg-day. The RfD is considered to be the dose for humans, with uncertainty of an order of magnitude or greater, at which adverse effects are not expected to occur. The noncancer hazard for inhaled noncarcinogens is the reference concentration (RfC) and also represents an estimate of toxicity when applied to the airborne concentration to which the person is exposed. The RfC is expressed in units of mg/m³ and also represents an estimate of noncancer hazard when applied to the airborne concentration to which the person is exposed.

Dermal SFs and RfDs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (ABS_{GI}), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the ABS_{GI}. The oral SF is divided, rather than multiplied, by the ABS_{GI} because SFs are expressed as reciprocal doses.

Toxicity values were chosen using the following hierarchy:

- USEPA's on-line integrated risk information system (IRIS) database (USEPA, 2006) containing toxicity values that have undergone the most rigorous Agency review
- Toxicity values provided in TCEQ (1998) guidance or in 30TAC§350 guidance as updated through March 2006.
- The ABS_{GI} values used to derive dermal RfDs and SFs from the corresponding oral toxicity values were obtained from TCEQ guidance (TCEQ, 1998).

Toxicity values for the 2,3,7,8-TCDD TEQ dioxin surrogate were evaluated using the following documents:

- USEPA's on-line integrated risk information system (IRIS) database (USEPA, 2006) containing toxicity values that have undergone the most rigorous Agency review
- Toxicity values provided in TCEQ (1998) guidance or in 30TAC§350 guidance as updated through March 2006.
- *Human Health Medium-Specific Screening Levels*, November 2004, (USEPA, 2004) accessed online in January 2006.
- *Health Effects Assessment Summary Tables (HEAST)*, (USEPA, 1997), adopted in the USEPA (2004) document.
- The ABS_{GI} values used to derive dermal RfDs and SFs from the corresponding oral toxicity values were obtained from TCEQ guidance (TCEQ, 1998, 2004).

Toxicity factors used in the evaluation of cancer risk and noncancer hazard are shown in **Table D-5**.

5.0 Risk Characterization

Risk characterization is the combination of the results of the exposure assessment and toxicity assessment to yield a quantitative expression of cancer risk for the exposed receptors. This quantitative expression is the probability of developing cancer. Quantitative estimates are developed for individual chemicals, exposure pathways, and exposure media for each receptor. The risk characterization follows USEPA (1989) methodology as modified by more recent information and guidance. The USEPA methods are, appropriately, designed to be health-protective and tend to overestimate, rather than underestimate, risk.

5.1 Carcinogenic Effects of Chemicals

The risk from exposure to chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime, and is called the incremental lifetime cancer risk (ILCR). In the low-dose range, which would be expected for most environmental exposures, cancer risk from exposure by ingestion and dermal exposures is estimated from the following linear equation (USEPA, 1989):

$$ILCR = (CDI)(SF) \quad \text{Equation D-12}$$

where:

- ILCR = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence (calculated)
- CDI = chronic daily intake (mg/kg-day), calculated as (see Equation D-3) or DAD (Equation D-10)
- SF = cancer slope factor (per mg/kg-day).

The cancer risk from exposure to carcinogens by the inhalation pathway is estimated from the following linear equation (TCEQ, 1998):

$$ILCR = (C_a)(URF) \quad \text{Equation D-13}$$

where:

- ILCR = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence (calculated)
- C_a = concentration of carcinogenic COPC in airborne dust ($\mu\text{g}/\text{m}^3$) (see Equation D-6)

URF = cancer slope factor (per $\mu\text{g}/\text{m}^3$).

As a matter of policy, USEPA (1989) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemical's mechanisms of toxicity or sites (organs of the body) of action. Cancer risk arising from simultaneous exposure by a given pathway to multiple chemicals is estimated from the following equation:

$$Risk_p = ILCR_{(chem\ 1)} + ILCR_{(chem\ 2)} + \dots + ILCR_{(chem\ i)} \quad \text{Equation D-14}$$

where:

Risk_p = total pathway risk of cancer incidence (calculated)
ILCR(chem_i) = individual chemical cancer risk

The total cancer risk for a given receptor from all pathways is summed across pathway risks in the same manner.

5.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects are evaluated by comparing an exposure level or intake with an RfD. The HQ from exposure by ingestion and dermal exposures, defined as the ratio of intake to RfD, is estimated as (USEPA, 1989):

$$HQ = I / RfD \quad \text{Equation D-15}$$

where:

HQ = hazard quotient (unitless, calculated)
I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day); I_s (see Equation D-4) or DAD (see Equation D-11)
RfD = reference dose (mg/kg-day)

Chemical noncancer hazards are evaluated using chronic RfD values. This approach is different from the probabilistic approach used to evaluate cancer risks. An HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than the RfD. An HQ of unity indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects.

The noncancer hazard from exposure by the inhalation pathway is estimated from the following linear equation (TCEQ, 1998):

$$HQ = (C_a) / (RfC) \quad \text{Equation C-16}$$

where:

HQ	=	hazard quotient (unitless, calculated)
C _a	=	concentration of noncarcinogenic COPC in airborne dust (mg/m ³) (see Equation D-6)
RfC	=	reference concentration (mg/m ³).

In the case of simultaneous exposure of a receptor to several chemicals, an HI is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \dots HQ_i \quad \text{Equation C-17}$$

where:

HI	=	hazard index (unitless, calculated)
HQ _i	=	hazard quotient for the i th toxicant.

5.3 Risks Associated With Exposure to Soil

Mercury and dioxins were identified as COPCs in soil (**Table D-3**). The estimated cancer risk and noncancer hazard from potential exposure to by the ingestion pathway are shown in **Tables D-6a** and **D-6b**. The cancer risks and noncancer hazards from potential exposures by the inhalation and dermal exposure pathways are shown in **Tables D-7a** and **D-7b**, and **Tables D-8a** and **D-8b**, respectively. Total cancer risk and noncancer hazard estimated for exposures of the potential resident to all COPCs by all pathways are shown in **Table D-9a**.

The total cancer risk (8E-06, **Table D-9a**) is within the acceptable range of (1E-06 to 1E-04) (USEPA, 1994). The noncancer hazard (Total HI, 3E-01, **Table D-9b**) is less than 1 and is, therefore, below acceptable limits (USEPA, 1994). Therefore, chemicals are not of concern for exposures of potential residents to soil at LHAAP-35C(53).

6.0 *Uncertainty Analysis*

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements, e.g., analytical accuracy and precision associated with contaminant concentrations. The results of this risk assessment reflect the accumulated variances of the individual measured values.

A different kind of uncertainty stems from data gaps, i.e., additional information needed to complete the database for the assessment, uncertainties associated with exposure parameters assumed for children and adults (**Table D-3**), toxicity factors used in the characterization of risk associated with dioxins (**Table D-4**), and assumptions regarding additivity of risk and hazard estimates (**Sections 5.1**). The methodology accounts for these uncertainties by using various conservative assumptions that result in overestimations of risks. This risk assessment incorporates all of these uncertainties, which are discussed in detail in USEPA (1989) guidance and the previous risk assessment (Jacobs, 2003).

The assumption that potential residents would be exposed to the maximum concentration of all COPCs represents a conservative assumption leading to an expected over-estimation of risk at LHAAP-35C(53).

7.0 References

Jacobs, 2002, *Final Remedial Investigation Report, Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60,67, Goose Prairie Creek, Volumes 1 and 2:: Report, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee, April.*

Jacobs, 2003, *Draft Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60,67, Goose Prairie Creek, Saunder's Branch, and Caddo Lake, Volume 1, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee, June.*

Plexus Scientific, Inc. (Plexus), 2005, *Final Environmental Site Assessment Phase I and II Report, Production Areas, Longhorn Army Ammunition Plant, Karnack, Texas, February.*

Shaw Environmental, Inc. (Shaw), 2004a, *Final Work Plan Groundwater Data Gaps Investigation Groups 2 and 4, Longhorn Army Ammunition Plant, Karnack, Texas, Houston, Texas, February.*

Shaw, 2004b, *Final Installation-Wide Background Study Work Plan, Longhorn Army Ammunition Plant, Karnack, Texas, Houston, Texas, January.*

Shaw, 2004c, *Final Background Soil Study Report, Longhorn Army Ammunition Plant, Karnack Texas, Houston, Texas, July.*

Shaw, 2005, *Final Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas, Houston, Texas, May.*

Shaw, 2006, *Final Modeling Report, Derivation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army ammunition Plant, Karnack, Texas, September.*

StatSoft, Inc. 1997. *STATISTICA for Windows Version 5.1*, Tulsa, OK, <<http://www.statsoft.com>> (February 2004).

Texas Commission on Environmental Quality (TCEQ), 1998, Interoffice Memorandum from Ronald R. Pedde to Remediation Division Staff regarding implementation of the existing risk reduction rules (a.k.a. TNRCC Consistency Memorandum), July.

TCEQ, 2001. Interoffice Memorandum from Joseph T. Haney, Jr., (TCEQ) to Camarie Perry, Office of Permitting, Remediation & Registration, *Evaluation of the Potential Health Impacts of Exposure to Iron, Calcium, Magnesium, Potassium, sodium, and Phosphorus through Soil Ingestion*, October.

TCEQ, 2003, Interoffice Memorandum, *Compounds for which Calculation of a Human Health MSC is Not Required*, October, available online <http://www.tnrcc.state.tx.us/permitting/rrr.htm>

TCEQ, 2004, Texas Risk Reduction Rules (30TAC§335) as updated through March 2006.

TCEQ, 2005, Texas Risk Reduction Program (30TAC§350) as updated through March 2006.

U.S. Environmental Protection Agency (USEPA), 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-0202, March.

USEPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, EPA/540/1-89/002, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, September.

USEPA, 1992a, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Third Edition (September, 1992), with Updates I-III*.

USEPA, 1992b, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*, EPA/530/R-93/003, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, July.

USEPA, 1992c, *Guidance for Data Usability in Risk Assessment (Part A)*, EPA Publication 9285.7-09A, PB92-973356, Office of Emergency and Remedial Response, April.

USEPA, 1994, *National Oil and Hazardous Substances Pollution Contingency Plan*, 40 *Code of Federal Regulations* Part 300, 59 *Federal Register* 47384, October 10.

USEPA, 1997, Health Effects Assessment Summary Tables (HEAST), U.S. Environmental Protection Agency, office of Solid Waste and Emergency Response, July, as incorporated in USEPA, 2004.

USEPA, 2002a, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, EPA 540-R-01-003, OSWER 9285.7-41, Office of Environmental and Remedial Response, September.

USEPA, 2002b, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, OSWER 9285.6-10, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

USEPA, 2004, EPA Region 6, Human Health, Medium-Specific Screening Levels, Dallas, Texas, November, accessed at http://www.epa.gov/earthlr6/6pd/rcra_c/pd-n/screen.htm (January 2006).

USEPA, 2006, Integrated Risk Information System (IRIS), U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. accessed at <<http://www.epa.gov/iris>, January 2006.

Van den Berg, M., Birnbaum, L., Bosveld, A.T.C., Brunstrom, B., Cook, P., Feeley, M., Giesy, J.P., Hanberg, A., Hasegawa, R., Kennedy, S.W., Kubiak, T., Larsen, J.C., van Leeuwen, F.X.R., Liem, A.K.D., Nolt, C., Peterson, R.E., Poellinger, L., Safe, S., Schrenk, D., Tillitt, D., Tysklind, M., Younes, M., Waern, F. and Zacharewski, T., 1998, *Toxic Equivalency Factors (TEFs) for*

PCBs, PCDDs, PCDFs for Humans and Wildlife, Environmental Health Perspectives
106(12):775-792.

Tables

Table D-1
Soil Sample Summary
LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Location	Sample Number	Purpose	Type	Sample Date	Depth (ft)	Analyses
Soil ^a						
LH-DL102-01	LH-DL102-01	REG	SS	3-Aug-93	2 - 4	Metals, SVOC, VOC
LH-DL103-01	LH-DL103-01	REG	SS	25-Jul-93	2 - 4	Explosives ^b , Metals, SVOC, VOC
LH-DL104-01	LH-DL104-01	REG	SS	4-Aug-93	2 - 4	Metals, SVOC, VOC
LH-DL105-01	LH-DL105-01	REG	SS	3-Aug-93	2 - 4	Metals, SVOC, VOC
LH-S102-01	LH-S102-01_1	REG	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S102-01	LH-S102-01 QC	FD	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S102-01	LH-S102-01_2	REG	DS	3-Aug-93	4 - 6	Metals, SVOC, VOC
LH-S102-02	LH-S102-02_1	REG	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S102-02	LH-S102-02_2	REG	DS	3-Aug-93	4 - 6	Metals, SVOC, VOC
LH-S103-01	LH-S103-01_1	REG	SS	24-Jul-93	0.5 - 2	Metals, SVOC, VOC
LH-S103-01	LH-S103-01_2	REG	DS	24-Jul-93	4 - 6	Metals, SVOC, VOC
LH-S103-01	LH-S103-01_3	REG	DS	24-Jul-93	9 - 11	Metals, SVOC, VOC
LH-S103-02	LH-S103-02_1	REG	SS	25-Jul-93	0.5 - 2	Metals, SVOC, VOC
LH-S103-02	LH-S103-02_2	REG	DS	25-Jul-93	4 - 6	Metals, SVOC, VOC
LH-S103-02	LH-S103-02_3	REG	DS	25-Jul-93	9 - 11	Metals, SVOC, VOC
LH-S104-01	LH-S104-01_1	REG	SS	3-Aug-93	1.5 - 2.5	Metals, SVOC, VOC
LH-S104-01	LH-S104-01_2	REG	DS	3-Aug-93	9 - 11	Metals, SVOC, VOC
LH-S104-02	LH-S104-02_1	REG	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S104-02	LH-S104-02 QC	FD	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S104-02	LH-S104-02_2	REG	DS	3-Aug-93	7 - 9	Metals, SVOC, VOC
LH-S105-01	LH-S105-01_1	REG	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S105-01	LH-S105-01_2	REG	DS	3-Aug-93	4 - 6	Metals, SVOC, VOC
LH-S105-02	LH-S105-02_1	REG	SS	3-Aug-93	0.5 - 2	Metals, SVOC, VOC
LH-S105-02	LH-S105-02_2	REG	DS	3-Aug-93	4 - 6	Metals, SVOC, VOC
LHSMW67	LHS-MW67	REG	SST	5-Oct-94	0 - 0.5	Explosives, Metals, SVOC, VOC
LHSMW68	LHS-MW68	REG	SST	5-Oct-94	0 - 0.5	Explosives, Metals, SVOC, VOC
LHSMW69	LHS-MW69	REG	SST	5-Oct-94	0 - 0.5	Explosives, Metals, SVOC, VOC
LHSMW70	LHS-MW70	REG	SST	5-Oct-94	0 - 0.5	Explosives, Metals, SVOC, VOC
LHSMW70	LHS-MW70 QC	FD	SST	5-Oct-94	0 - 0.5	Metals, SVOC, VOC
LHSMW71	LHS-MW71	REG	SST	5-Oct-94	0 - 0.5	Explosives, Metals, SVOC, VOC
LHS-T-01	LHS-T-01	REG	SLDG	11-Jan-95	0 - 0.5	Explosives, Metals, SVOC, VOC
35CSB01	35CSB01(0-0.5)	REG	SST	27-Jul-98	0 - 0.5	Dioxins, Explosives, Metals, Pest, PCB, SVOC, VOC
35CSB01	35CSB01(0-0.5)QC	FD	SST	27-Jul-98	0 - 0.5	Dioxins, Explosives, Metals, Pest, PCB, SVOC, VOC
35CSB01	35CSB01(1-3)	REG	SS	27-Jul-98	1 - 3	Dioxins, Explosives, Metals, Pest, PCB, SVOC, VOC
35CSB01	35CSB01(3-5)	REG	DS	27-Jul-98	3 - 5	Dioxins, Explosives, Metals, Pest, PCB, SVOC, VOC
SUMP105	SUMP105(0-0.5)	REG	SST	11-Aug-98	0 - 0.5	Dioxins, Explosives, Metals, PCB, SVOC, VOC
SUMP105	SUMP105(3-5)	REG	DS	11-Aug-98	3 - 5	Dioxins, Explosives, Metals, PCB, SVOC, VOC
35CSB02	35CSB02(0-0.5)	REG	SST	1-Jun-00	0 - 0.5	Perchlorate
35CSB02	35CSB02(1-2)	REG	SS	1-Jun-00	1 - 2	Perchlorate
35CSB03	35CSB03(0-0.5)	REG	SST	1-Jun-00	0 - 0.5	Perchlorate
35CSB03	35CSB03(1-2)	REG	SS	1-Jun-00	1 - 2	Perchlorate

^a Surface soil is defined as 0 to 15 feet below ground surface.

^b Explosive analysis includes only 2,4- and 2,6-dinitrotoluene.

DS = Subsurface soil sample

FD = Field duplicate; the field duplicate was averaged with the regular sample to produce one result for the same sample location and depth.

PCB = Polychlorinated biphenyls

Pest = Organochlorine pesticides

REG = Regular environmental sample

SLDG = Sludge sample

SS = Surface soil sample

SST = Surface soil-top layer sample

SVOC = Semivolatile organic compound

VOC = Volatile organic compound

ft = feet below ground surface

Table D-2
Concentrations of 2,3,7,8-TCDD Toxicity Equivalent Quotient Dioxin and Furan Congeners in Soil at LHAAP- 35C(53)

Location:		35CSB01		35CSB01		35CSB01		SUMP105		SUMP105		
Sample Number:		35CSB01(0-0.5)		35CSB01(1-3)		35CSB01(3-5)		SUMP105(0-0.5)		SUMP105(3-5)		
Date Sampled:		7/27/1998		7/27/1998		7/27/1998		8/11/1998		8/11/1998		
Depth (ft.):		0-0.50		1-3		3-5		0-0.50		3-5		
		Concentration		Concentration		Concentration		Concentration		Concentration		
DIOXIN AND FURAN CONGENERS		TEF	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ	(ng/kg)	TEQ
1,2,3,7,8-PENTACHLORODIBENZO-p-DIOXIN		1	0.052	5.20E-02	1.267	1.27E+00	0.038	3.80E-02	0.093	9.30E-02	0.117	1.17E-01
1,2,3,4,7,8-HEXACHLORODIBENZO-p-DIOXIN		0.1	0.033	3.30E-03	10.646	1.06E+00	0.348	3.48E-02	0.17	1.70E-02	0.285	2.85E-02
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN		0.1	0.772	7.72E-02	52.792	5.28E+00	2.119	2.12E-01	0.654	6.54E-02	0.159	1.59E-02
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN		0.1	0.203	2.03E-02	21.791	2.18E+00	0.952	9.52E-02	1.273	1.27E-01	0.189	1.89E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN		0.01	20.704	2.07E-01	1453.11	1.45E+01	68.28	6.83E-01	60.154	6.02E-01	3.147	3.15E-02
OCTACHLORODIBENZO-p-DIOXIN		0.0001	141.093	1.41E-02	7068.108	7.07E-01	450.139	4.50E-02	17491.922	1.75E+00	340.795	3.41E-02
2,3,7,8-TETRACHLORODIBENZOFURAN		0.1	0.464	4.64E-02	0.476	4.76E-02	0.394	3.94E-02	0.115	1.15E-02	0.173	1.73E-02
2,3,4,7,8-PENTACHLORODIBENZOFURAN		0.5	0.042	2.10E-02	0.139	6.95E-02	0.021	1.05E-02	0.051	2.55E-02	0.105	5.25E-02
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN		0.1	0.482	4.82E-02	19.746	1.97E+00	0.856	8.56E-02	0.469	4.69E-02	0.13	1.30E-02
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN		0.1	0.03	3.00E-03	4.069	4.07E-01	0.203	2.03E-02	0.055	5.50E-03	0.087	8.70E-03
2,3,4,6,7,8-HEXACHLORODIBENZOFURAN		0.1	0.033	3.30E-03	5.037	5.04E-01	0.311	3.11E-02	0.08	8.00E-03	0.127	1.27E-02
1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN		0.01	3.203	3.20E-02	218.228	2.18E+00	9.51	9.51E-02	2.182	2.18E-02	0.11	1.10E-03
1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN		0.01	0.178	1.78E-03	11.969	1.20E-01	0.518	5.18E-03	0.097	9.70E-04	0.14	1.40E-03
OCTACHLORODIBENZOFURAN		0.0001	11.88	1.19E-03	904.49	9.04E-02	51.12	5.11E-03	7.395	7.40E-04	0.1	1.00E-05
2,3,7,8-TCDD-TEQ concentration (mg/kg) ^a =			5.31E-07			3.04E-05		1.40E-06		2.77E-06		3.53E-07
Exposure Point Concentration of 2,3,7,8-TCDD TEQ used in risk assessment = 3.04E-05 mg/kg, the maximum value.												

Notes:

a 2,3,7,8-TCDD TEQ value is sum of TEQ values for congeners in the sample.

TEF: Toxicity Equivalent Factor. Van den Berg, M. et al., 1998, Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife. Environmental Health Perspectives 106(12):775-792.

Table D-3
Surface Soil Samples^a
LHAAP-35C(53)

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg		Statistical Distribution ^b	Mean mg/kg	Standard Deviation	95% UCL ^c mg/kg	Screening Concentration ^d mg/kg	Background mg/kg	Texas	UPL mg/kg	COPC? ^{f,g}	Source-Term
			Detected Concentrations Minimum - Maximum	Reporting Limits Minimum - Maximum							RBSV ^e mg/kg			Concentration mg/kg
Inorganics														
Aluminum	25 / 32	78	4.85E+03 - 2.38E+04	1.23E+01 - 1.80E+04	U	1.17E+04	6.19E+03		2.38E+04		1.5E+04	1.89E+04	N (c)	---
Arsenic	32 / 32	100	1.40E+00 - 1.62E+01	2.50E-01 - 1.30E+00	U	4.36E+00	3.10E+00		6.89E+00		2.0E+01	5.86E+00	N (a)	---
Barium	32 / 32	100	3.86E+01 - 1.50E+02	3.10E+00 - 2.20E+01	U	8.52E+01	3.08E+01		1.36E+02		9.1E+02	1.16E+02	N (a)	---
Beryllium	3 / 3	100	7.26E-01 - 1.02E+00	5.43E-01 - 5.62E-01	U	8.26E-01	1.68E-01		8.85E-01		4.6E+00	7.69E-01	N (a)	---
Cadmium	1 / 32	3	1.60E+00 - 1.60E+00	5.43E-01 - 1.30E+00	U	4.89E-01	2.21E-01		1.40E+00		5.2E+00	1.40E+00	N (a)	---
Calcium	31 / 32	97	2.57E+02 - 2.86E+04	6.10E+00 - 5.60E+02	U	2.15E+03	4.88E+03		3.84E+03	Not Required		2.52E+03	N (b)	---
Chromium	32 / 32	100	7.30E+00 - 4.98E+01	1.10E+00 - 2.60E+00	U	2.04E+01	9.18E+00		3.55E+01		5.9E+03	2.90E+01	N (a)	---
Cobalt	32 / 32	100	1.60E+00 - 2.98E+01	1.20E+00 - 5.60E+00	U	8.95E+00	5.81E+00		8.34E+00		1.5E+03	7.11E+00	N (a)	---
Copper	32 / 32	100	2.82E+00 - 1.49E+01	1.20E+00 - 2.81E+00	U	6.88E+00	2.24E+00		1.04E+01		1.0E+03	8.37E+00	N (a)	---
Iron	25 / 32	78	9.60E+03 - 5.07E+04	1.90E+00 - 2.23E+04	U	1.72E+04	9.08E+03		3.49E+04	Not Required		2.79E+04	N (b)	---
Lead	32 / 32	100	3.10E+00 - 2.85E+01	3.26E-01 - 5.90E+00	U	1.07E+01	5.72E+00		2.03E+01		5.0E+02	1.78E+01	N (a)	---
Magnesium	32 / 32	100	2.99E+02 - 2.38E+03	1.23E+01 - 5.60E+02	U	1.39E+03	5.99E+02		1.59E+03	Not Required		1.24E+03	N (b)	---
Manganese	32 / 32	100	4.50E+01 - 5.13E+02	6.10E-01 - 1.69E+00	U	1.30E+02	1.06E+02		2.24E+03		1.7E+03	1.34E+03	N (a)	---
Mercury	1 / 32	3	2.40E-01 - 2.40E-01	9.00E-02 - 1.30E-01	U	5.68E-02	3.36E-02		1.34E-01		1.1E-02	1.10E-01	Y	2.40E-01
Nickel	3 / 3	100	8.90E+00 - 1.70E+01	4.30E+00 - 4.50E+00	U	1.23E+01	4.22E+00		1.13E+01		1.9E+02	9.40E+00	N (a)	---
Potassium	32 / 32	100	2.89E+02 - 1.86E+03	1.23E+02 - 5.60E+02	U	1.02E+03	4.24E+02		5.46E+02	Not Required		4.61E+02	N (b)	---
Selenium	9 / 32	28	1.60E-01 - 2.15E+00	1.20E-01 - 1.12E+00	U	5.61E-01	3.15E-01		6.96E+00		1.3E+02	5.61E+00	N (a)	---
Silver	5 / 32	16	8.10E-01 - 5.15E+00	6.10E-01 - 1.30E+00	U	7.46E-01	8.58E-01		3.70E-01		4.7E+01	3.70E-01	N (a)	---
Strontium	29 / 32	91	7.00E+00 - 4.95E+01	5.40E+00 - 1.31E+01	U	1.75E+01	1.03E+01		3.17E+01		1.2E+04	2.48E+01	N (a)	---
Vanadium	3 / 3	100	1.60E+01 - 2.30E+01	5.40E+00 - 5.60E+00	U	2.03E+01	3.79E+00		5.29E+01		4.8E+01	4.44E+01	N (a)	---
Zinc	32 / 32	100	2.04E+01 - 2.27E+02	6.10E-01 - 2.20E+00	U	5.19E+01	3.46E+01		2.94E+01		5.9E+03	2.45E+01	N (a)	---
Perchlorate														
Perchlorate	1 / 4	25	6.09E-02 - 6.09E-02	5.96E-03 - 6.84E-03	U	1.76E-02	2.89E-02				1.4E+01		N (a)	---
Dioxins/Furans														
2,3,7,8-TCDD - Total TEQ	5 / 5	100	3.53E-07 - 3.04E-05	NA - NA	U	7.10E-06	1.31E-05		4.41E-06		3.9E-06	3.96E-06	Y	3.04E-05
Organochlorine Pesticides														
4,4'-DDE	1 / 3	33	3.70E-03 - 3.70E-03	3.60E-03 - 3.70E-03	U	2.45E-03	1.08E-03		3.80E-03		1.7E+00	3.80E-03	N (a)	---
4,4'-DDT	1 / 3	33	9.90E-03 - 9.90E-03	3.60E-03 - 3.70E-03	U	4.52E-03	4.66E-03		6.40E-03		1.7E+00	6.40E-03	N (a)	---
Semivolatile Organics														
Benzo(a)anthracene	1 / 32	3	1.40E-01 - 1.40E-01	3.30E-01 - 5.20E-01	U	1.71E-01	1.83E-02		1.53E-02		6.3E-01	1.53E-02	N (a)	---
Benzo(a)pyrene	1 / 32	3	1.10E-01 - 1.10E-01	1.80E-01 - 5.20E-01	U	1.61E-01	3.04E-02		1.54E-02		6.3E-02	1.54E-02	N (d)	---
Benzo(b)fluoranthene	1 / 32	3	2.80E-01 - 2.80E-01	3.30E-01 - 5.20E-01	U	1.75E-01	2.59E-02		1.53E-02		6.3E-01	1.53E-02	N (a)	---
Benzo(k)fluoranthene	1 / 32	3	1.10E-01 - 1.10E-01	3.30E-01 - 5.20E-01	U	1.70E-01	2.05E-02		1.30E-02		6.3E+00	1.30E-02	N (a)	---
Benzoic Acid	1 / 32	3	4.68E-01 - 4.68E-01	9.05E-01 - 2.60E+00	U	8.14E-01	1.74E-01				6.2E+04		N (a)	---
bis(2-Ethylhexyl)phthalate	6 / 32	19	3.60E-02 - 5.80E-01	3.30E-01 - 5.20E-01	U	1.69E-01	8.49E-02				1.7E+01		N (a)	---
Butyl benzyl phthalate	1 / 32	3	2.20E-01 - 2.20E-01	3.30E-01 - 5.20E-01	U	1.73E-01	1.94E-02				3.1E+03		N (a)	---
Chrysene	1 / 32	3	2.90E-01 - 2.90E-01	3.30E-01 - 5.20E-01	U	1.75E-01	2.72E-02		1.51E-02		6.3E+01	1.51E-02	N (a)	---
di-n-Butyl phthalate	5 / 32	16	6.60E-02 - 7.90E-02	3.30E-01 - 5.20E-01	U	1.57E-01	4.45E-02				1.5E+03		N (a)	---
Fluoranthene	4 / 32	13	5.35E-02 - 4.20E-01	3.30E-01 - 5.20E-01	U	1.68E-01	5.90E-02		2.29E-02		5.5E+02	2.29E-02	N (a)	---
Phenanthrene	2 / 32	6	4.10E-02 - 4.90E-02	3.30E-01 - 5.20E-01	U	1.66E-01	3.86E-02				2.5E+00		N (a)	---
Pyrene	2 / 32	6	1.12E-01 - 3.20E-01	3.30E-01 - 5.20E-01	U	1.74E-01	3.34E-02		1.94E-02		1.5E+01	1.94E-02	N (a)	---
Volatile Organics														
Acetone	1 / 32	3	5.25E-03 - 5.25E-03	1.00E-02 - 1.00E-01	U	3.74E-02	1.96E-02				1.7E+02		N (a)	---

Notes and Abbreviations:^a Surface soil is defined as the interval less than or equal to 15 feet below the ground surface. Soil samples were classified on the basis of the end depth of the sample.^b Statistical Distribution: U = Distribution not determined if chemical is not selected as a COPC, if sample size is less than 5, or if the Source Term Concentration is the maximum.^c 95% Upper confidence limit (UCL) not calculated if chemical is not selected as a COPC, or if sample size is less than 5.^d Background screening concentrations are based on the 95% upper prediction limit (UPL) of the total soil background data set, calculated for the combined depth intervals (i.e., 0-0.5 feet and 1.5-2.5 feet) from Shaw, 2004c.

Final Background Soil Study Report, Longhorn Army Ammunition Plant, July.

^e Based on Texas Risk-Based Screening Values (RBSVs) for soil, March 2006 update. Values are based on a cancer risk of 1E-6 and a hazard index of 0.1^f N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.^g Rationale for exclusion of chemical as a COPC:

(a) = maximum detected concentration is below or equal to risk-based screening concentration

(b) = essential nutrient; no screening value available/required

(c) = chemical concentration is below or equal to background screening concentration.

(d) = chemical is detected infrequently (i.e., < 5% frequency of detection).

(e) = chemical is consistent with background based on geochemical evaluation (Attachment B)

^h Concentration used in risk assessment equal to the maximum detected concentration.ⁱ Based on RBSV for total chromium.^j Based on the medium-specific screening level (MSSL) for dioxin (2,3,7,8-TCDD) from EPA Region 6 (USEPA Region 6, 2004, Human Health Medium-Specific Screening Levels 2004-2005, December).

NA = Not applicable

TEQ = Toxicity equivalency

UPL = Upper prediction limit of the Shaw total soil background dataset.

mg/kg = milligram per kilogram

Table D-4
Exposure Factors Used to Estimate Intake of COPCs
LHAAP-35C(53)

Residential Exposure Pathway		
General Factors	Factor Value	Reference
Exposure Frequency, EF (days/year or event/year, dermal)	350	a
Exposure Duration, ED (year) - Adult	24	a, b
Exposure Duration, ED (year) - Child	6	a
Exposure Duration, ED (year) - carcinogens, Adult	30	a, b
Body Weight, BW (kg) - Adult	70	a
Body Weight, BW (kg) - Child	15	a
Averaging Time-Noncarcinogens, ATs (year) - Adult	24	a, b
Averaging Time-Noncarcinogens, ATs (year) - Child	6	a
Averaging Time-carcinogens, ATc (year)	70	a
Ingestion of Soil		
Age-Adjusted Soil Ingestion Rate, IFadj (mg/year/kg-day)	114	a
Dermal Exposure to Soil		
Soil-to-Skin Adherence Factor, AF (mg/cm ² -event)	0.2	a
Averaging Time-Noncarcinogens, (dermal, child, resident) ATs (year)	6	a
Body Weight (residential, child, carcinogens), BW (kg)	15	a
Age-Adjusted Dermal Factor (carcinogens, resident) DF.adj (mg-yr/kg-event)	352	a, b
Exposure Duration (dermal, child, resident), ED (year)	6	a
Exposed Skin Surface Area, SA (cm ²) - Child	2200	a
Exposed Skin Surface Area, SA (cm ²) - Adult	2500	a

a Texas Commission on Environmental Quality (TCEQ) 30TAC§335.567 as updated through March 2006

b Value specified by TCEQ in comments on draft report, August 2006.

Table D-5
Toxicity Values for COPCs
LHAAP-35C(53) Site

Chemical	Weight of Evidence ^e	Oral Slope Factor SFO ^{b,c} 1/(mg/kg-day)	Inhalation Unit Risk Factor, URF ^{b,c,d} 1/(ug/m ³)	Inhalation Slope Factor SFI ^{b,c} 1/(mg/kg-day)	Oral Reference Dose, RfDo ^{b,c} (mg/kg-day)	Inhalation Reference Conc., RfC ^{b,c,d} (mg/m ³)	GI Absorption Factor, ABS.gi ^e (unitless)	Relative Dermal Absorption Factor, ABS.d ^c (unitless)
Inorganic Compounds								
Mercury	D	NA	NA	NA	3.0E-04	3.0E-04	7.00E-02	1.00E-02
Semivolatile Organic Compounds								
2,3,7,8-TCDD-TEQ	ND	1.5E+05	4.3E+01	1.5E+05	ND	ND	5.00E-01	3.00E-02

Notes and Abbreviations:

^a Weight of Evidence for carcinogenicity of chemical provided in the EPA Integrated Risk Information System (IRIS, Online, EPA, 2006).

^b USEPA, 2006: Human Health Medium-Specific Screening Levels, U. S. Environmental Protection Agency, Region 6, November 2004, accessed online in January 2006.

^c Health Effects Assessment Summary Tables (HEAST), U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, July 1997, adopted in USEPA, 2006.

^d The URF value for 2,3,7,8-TCDD was calculated using the equation: $URF(\mu g/m^3)^{-1} = SFinh (mg/kg-day)^{-1} \times 20 m^3/day / (70 kg \times 1000 \mu g/mg)$ as provided in TCEQ (1998) documents.

^e Texas Commission on Environmental Quality (TCEQ) 30 TAC Sec. 350 as updated through March 2006

D: Indicates chemical is not classifiable as to human carcinogenicity

NA: Not Applicable

ND: No Data

Table D-6a
Incremental Lifetime Cancer Risk (ILCR) for Potential Ingestion Exposure of Future Residents to
Chemicals from Soil at the LHAAP-35C(53) Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral Slope factor, SF 1/(mg/kg/d)	Weight of Evidence	Intake Dose ID (mg/kg/d)	Incremental Lifetime Cancer Risk, ILCR
Mercury	2.40E-01	NA	D	3.75E-07	0.00E+00
2,3,7,8-TCDD-TEQ	3.04E-05	1.50E+05	ND	4.75E-11	7.13E-06
TOTAL PATHWAY CANCER RISK					7.13E-06

Table D-6b
Hazard Index (HI) for Potential Ingestion Exposure of Future Residents to
Chemicals from Soil at the LHAAP-35C(53) Site
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral RfD (mg/kg/d)	Intake Dose ID (mg/kg/d)	Hazard Quotient HQ
Mercury	2.40E-01	3.00E-04	8.75E-07	2.92E-03
2,3,7,8-TCDD - Total TEQ	3.04E-05	ND	1.11E-10	0.00E+00
TOTAL PATHWAY HAZARD INDEX				2.92E-03

NA: Not applicable

ND: No data available

Table D-7a
Incremental Lifetime Cancer Risk (ILCR) for Potential Inhalation Exposure of Future Resident to
Airborne Chemicals from Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs, mg/kg	Weight of Evidence	Unit Risk Factor, URF 1/(microg/m ³)	Exposure Adjusted Air Concentration (mg/m ³)	Incremental Lifetime Cancer Risk (ICLR)
Mercury	2.40E-01	D	NA	3.36E-02	0.00E+00
2,3,7,8-TCDD-TEQ	3.04E-05	ND	4.3E+01	4.91E-11	2.11E-09
TOTAL PATHWAY CANCER RISK					2.11E-09

Table D-7b
Hazard Index (HI) for Potential Inhalation Exposure of Future Resident to
Airborne Chemicals from Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs, mg/kg	Reference Conc., RfC (mg/m ³)	Exposure Adjusted Air Concentration (mg/m ³)	Hazard Quotient HQ
Mercury	2.40E-01	3.0E-04	7.84E-05	2.61E-01
2,3,7,8-TCDD-TEQ	3.04E-05	ND	1.52E-13	0.00E+00
TOTAL PATHWAY HAZARD INDEX				2.61E-01

NA: Not applicable
 ND: No data available

Table D-8a
Incremental Lifetime Cancer Risk (ILCR) for Potential Dermal Exposure of Future Residents to
Chemicals from Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral	Gastrointestinal	Dermal	Absorption	Weight	Dermal	Incremental Lifetime Cancer Risk, ILCR
		Slope factor, SF 1/(mg/kg/d)	Absorption Factor, ABS _{GI} (unitless)	Slope factor, SF _d 1/(mg/kg/d)	Factor, ABS _d (unitless)	of Evidence	Absorbed Dose Dose, DAD (mg/kg/d)	
Mercury	2.40E-01	NA	7.00E-02	NA	1.00E-02	D	1.16E-08	0.00E+00
2,3,7,8-TCDD-TEQ	3.04E-05	1.50E+05	5.00E-01	1.50E+05	3.00E-02	ND	4.40E-12	6.06E-07
TOTAL PATHWAY CANCER RISK								6.06E-07

Table D-8b
Hazard Index (HI) for Potential Dermal Exposure of Future Residents to
Chemicals from Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical Name	Soil Concentration Cs (mg/kg)	Oral	Gastrointestinal	Dermal	Absorption	Dermal	Hazard Quotient HQ
		RfD (mg/kg/d)	Absorption Factor, ABS _{GI} (unitless)	RfD (mg/kg/d)	Factor, ABS _d (unitless)	Absorbed Dose Dose, DAD (mg/kg/d)	
Mercury	2.40E-01	3.00E-04	7.00E-02	2.10E-05	1.00E-02	6.75E-08	3.21E-03
2,3,7,8-TCDD-TEQ	3.04E-05	ND	5.00E-01	ND	3.00E-02	2.57E-11	0.00E+00
TOTAL PATHWAY HAZARD INDEX							3.21E-03

NA: Not applicable

ND: No data available

Table D-9a
Exposures and Incremental Lifetime Cancer Risks for Potential Exposure of Future Resident to
Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical	Source Term Concentration (mg/kg)	Soil Ingestion Cancer Risk (ILCR)	Soil Inhalation Cancer Risk (ILCR)	Dermal Cancer Risk (ILCR)
Mercury	2.40E-01	0.00E+00	0.00E+00	0.00E+00
2,3,7,8-TCDD-TEQ	3.04E-05	7.13E-06	2.11E-09	6.06E-07
Total Pathway ILCR		7.13E-06	2.11E-09	6.06E-07
Total ILCR ^a				8.E-06

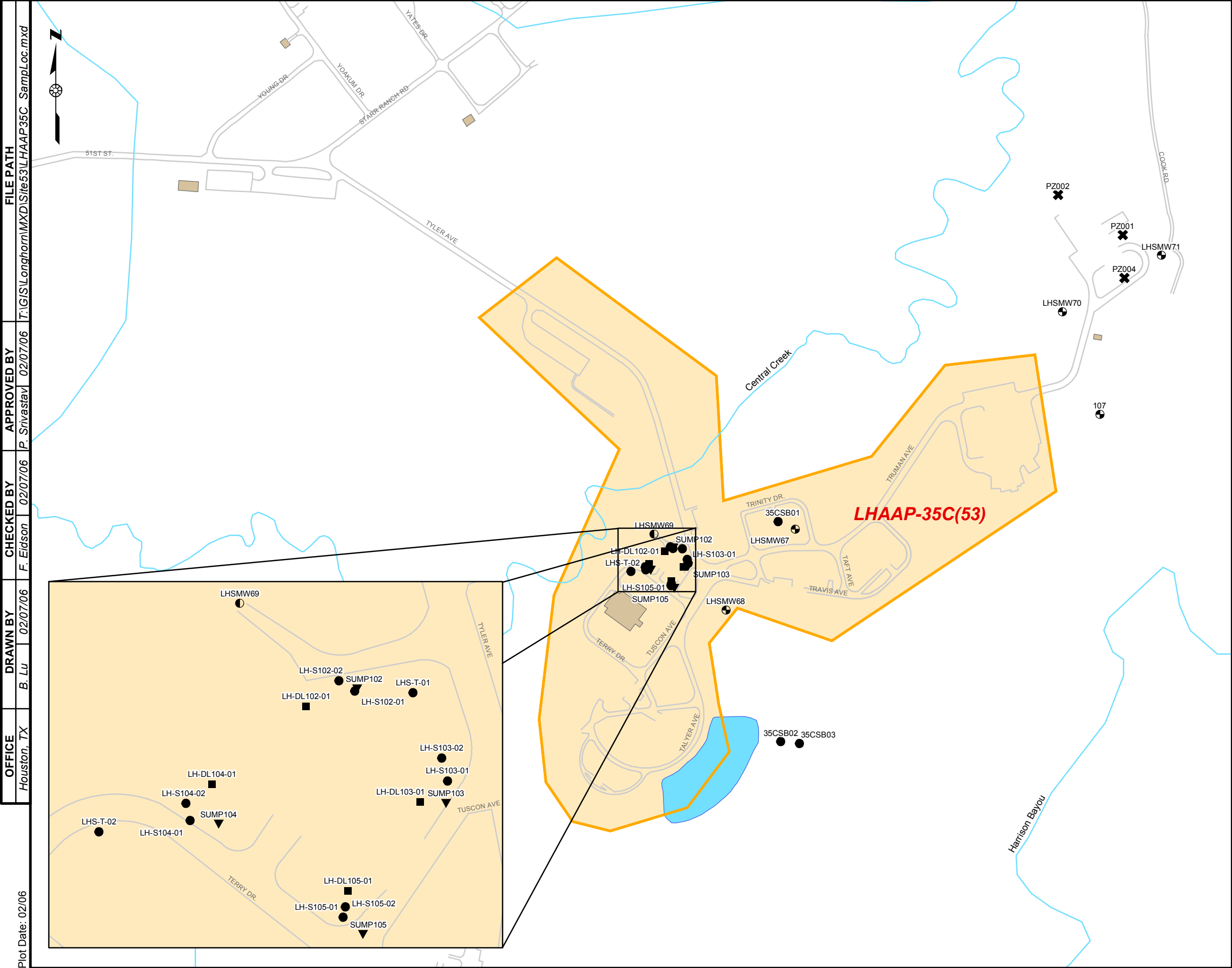
Table D-9b
Exposures and Noncancer Hazards for Potential Exposure of Future Resident to
Soil at the LHAAP-35C(53)
Longhorn Army Ammunition Plant
Karnack, Texas

Chemical	Source Term Concentration (mg/kg)	Soil Ingestion HQ	Soil Inhalation HQ	Dermal HQ
Mercury	2.40E-01	2.92E-03	2.61E-01	3.21E-03
2,3,7,8-TCDD - Total TEQ	3.04E-05	0.00E+00	0.00E+00	0.00E+00
Pathway Hazard Index (HI)		2.92E-03	2.61E-01	3.21E-03
Total HI ^a				3.E-01

Notes:

^a Total value reported to one significant figure

Figures



OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Lu	F. Eidson	P. Srivastav	T:\GIS\Longhorn\MXD\Site53\LHAAP35C_SampLoc.mxd

Plot Date: 02/06

Legend

- Shallow Monitoring Well
- Intermediate Monitoring Well
- Surface Soil
- Soil Boring
- Sump
- Piezometer
- Stream
- Road
- Existing Building
- Water Body
- Site

0 150 300 600 Feet



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

FIGURE D-1

SAMPLE LOCATION MAP
LHAAP-35C(53)

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Attachment 1

Statistical Comparison to Background Concentrations

Table 1
Concentrations of Aluminum in Soil for Comparison to Background

<u>Data Type</u>	<u>Al (mg/kg)</u>
Site 53	2620
Site 53	3880
Site 53	3995
Site 53	5800
Site 53	6350
Site 53	7750
Site 53	9000
Site 53	23800
Site 53	23300
Site 53	23200
Site 53	20100
Site 53	17300
Site 53	17200
Site 53	16700
Site 53	16500
Site 53	16100
Site 53	15700
Site 53	15400
Site 53	15300
Site 53	15000
Site 53	13700
Site 53	13010
Site 53	10500
Site 53	9700
Site 53	9450
Site 53	7980
Site 53	7440
Site 53	6050
Site 53	6000
Site 53	5890
Site 53	5550
Site 53	4850
BKG	1800
BKG	1850
BKG	1900
BKG	2080
BKG	2280
BKG	2510
BKG	2530
BKG	2690
BKG	2930
BKG	2990
BKG	3030
BKG	3210
BKG	3330
BKG	3560
BKG	3710
BKG	3780

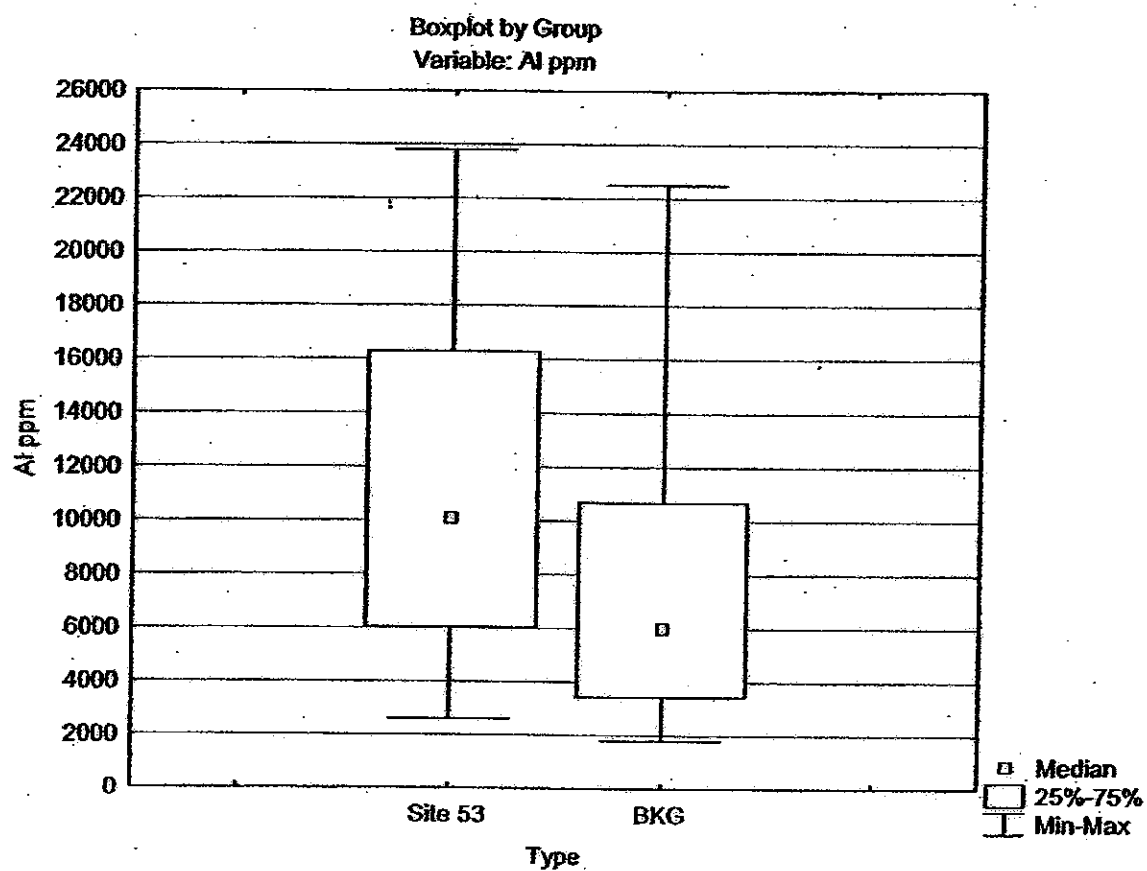
Table 1
Concentrations of Aluminum in Soil for Comparison to Background

BKG	3850
BKG	3940
BKG	3980
BKG	4000
BKG	4130
BKG	4390
BKG	4700
BKG	5180
BKG	5850
BKG	5980
BKG	6050
BKG	16300
BKG	3110
BKG	4250
BKG	6160
BKG	6840
BKG	7170
BKG	7940
BKG	8310
BKG	8380
BKG	8690
BKG	9030
BKG	9510
BKG	9660
BKG	10200
BKG	10300
BKG	10700
BKG	10700
BKG	11300
BKG	11600
BKG	11700
BKG	11700
BKG	12200
BKG	12900
BKG	12900
BKG	14600
BKG	14700
BKG	16100
BKG	21100
BKG	22500

Al: aluminum

BKG: background concentrations

ppm: parts per million. All soil concentrations are expressed in units of mg/kg.



Attachment 2

***Geochemical Evaluation of Aluminum in Soil Samples
LHAAP-35C(53)***

Geochemical Evaluation of Aluminum in Soil Samples LHAAP-35C(53) Longhorn Army Ammunition Plant

1.0 Introduction

This report provides the results of a geochemical evaluation of inorganic constituents in soil samples from the LHAAP-35C(53) site at Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. Aluminum failed statistical comparison to background, and a geochemical evaluation was performed to determine if the elevated concentrations in the site samples are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluation consist of 32 soil samples collected over a five-year period from July 1993 through July 1998. The samples were obtained at various depths ranging from 0 to 11 feet below ground surface, and they were analyzed for a full list of metals including aluminum, iron, and manganese. Installation-wide background data for target analyte list metals in soil are provided in the background study report (Shaw Environmental, Inc., 2004) and are used in the following evaluation.

2.0 Results of the Geochemical Evaluation of Aluminum In Soil

This section presents the results of the geochemical evaluation of aluminum in soil samples from LHAAP-35C(53). Correlation plots and ratio plots are provided in **Figures 1** through **5**.

2.1 Aluminum

Aluminum is the second most abundant of the 23 elements analyzed in the LHAAP-35C(53) soil samples, with a mean concentration of 13,400 milligrams per kilogram (mg/kg) (1.3 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Iron is the most abundant element analyzed in the site soil samples (mean concentration of 19,500 mg/kg, or approximately 2 weight percent) and is dominantly present as iron oxides. Iron oxides are common soil-forming minerals, and they occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. A plot of aluminum versus iron concentrations can be used to qualitatively assess the relative abundance of these minerals in site soil (**Figure 1**). As seen in the plot, the background samples and most of the site

samples form a common linear trend with a positive slope. Most of the site samples with high aluminum concentrations also contain proportionally higher iron concentrations, and they lie on the background trend. Aluminum in these samples is natural. Site samples LHS-MW69 and LHS-MW71 lie below the linear trend and exhibit anomalously low Al/Fe ratios relative to the other samples; however, the aluminum concentrations in these samples (9,450 mg/kg and 5,550 mg/kg) are well within the background range.

Magnesium and potassium are common components of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Clays are characterized by large surface-area-to-volume ratios and strong negative surface charges. As a result, the major cations, such as magnesium and potassium, are attracted to these mineral surfaces and take part in cation exchange reactions. Positive correlations for aluminum versus magnesium concentrations and aluminum versus potassium concentrations are thus typically observed for uncontaminated soil samples. Plots of aluminum versus magnesium and aluminum versus potassium for the LHAAP-35C(53) and background samples reveal linear trends with positive slopes (**Figures 2 and 3**). The site samples with the highest aluminum concentrations have proportionally higher magnesium and potassium content, and they exhibit Al/Mg and Al/K ratios that are within the background range (**Figures 4 and 5**). All of these observations suggest a natural source for the elevated aluminum detections in the LHAAP-35C(53) samples.

The site data set includes seven samples collected in July 1993 that are nondetect for aluminum and possess high reporting limits. These samples could not be included in the geochemical evaluation because their actual aluminum concentrations are unknown. However, the reporting limits for these samples range from 5,240 mg/kg to 18,000 mg/kg (mean of 11,250 mg/kg), and all of these values are below the background upper prediction limit of 18,900 mg/kg. The actual aluminum concentrations are somewhere below their respective reporting limits and, hence, they are below the background screening value as well. Contamination is not suspected in these samples.

2.2 Summary

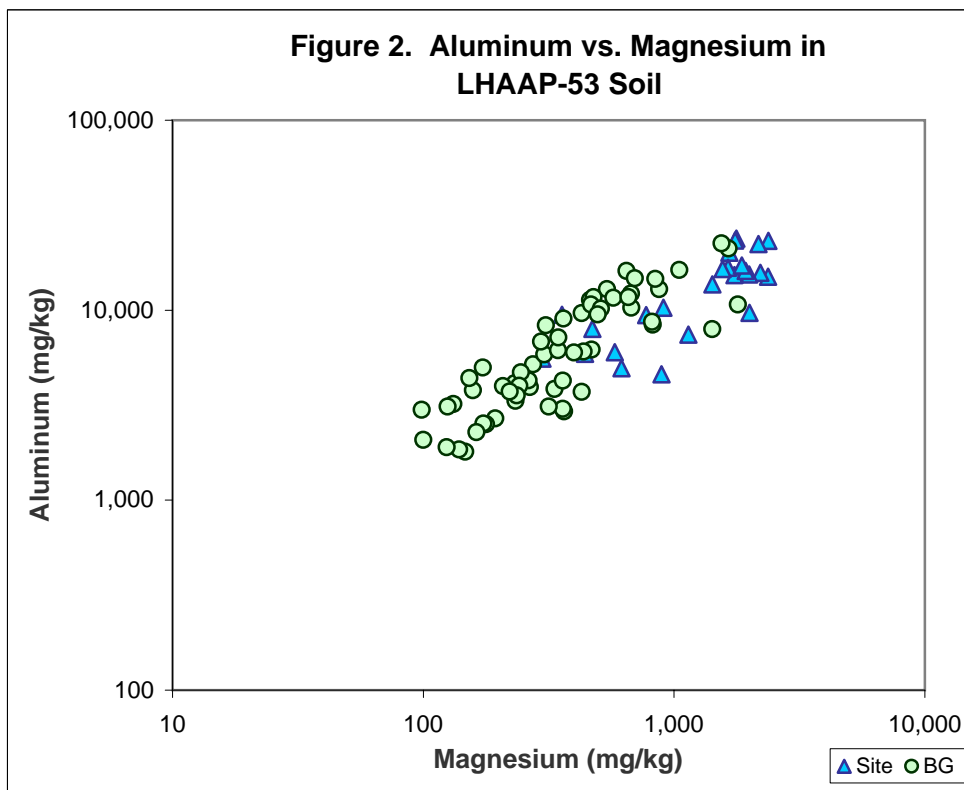
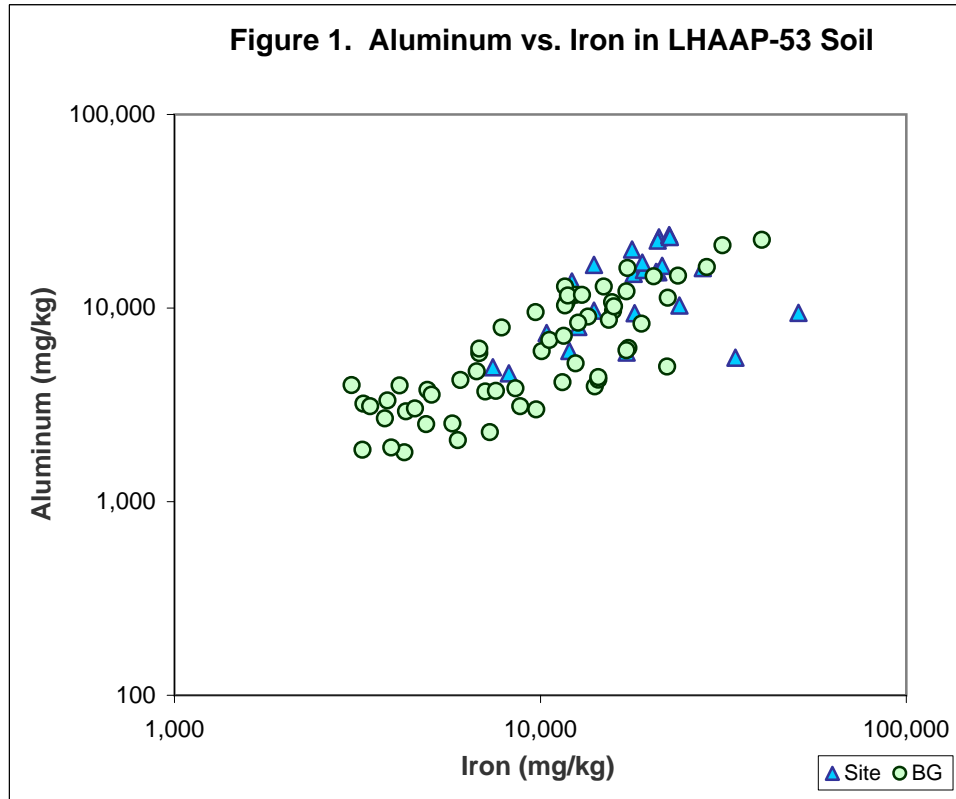
Aluminum in the LHAAP-35C(53) soil data set failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated site concentrations could be explained as the result of natural processes. Geochemical evaluation indicates that the detected concentrations of aluminum in the site soil samples are naturally occurring. The elevated aluminum concentrations observed in several site samples most likely reflect a higher proportion of clay minerals relative to the other samples.

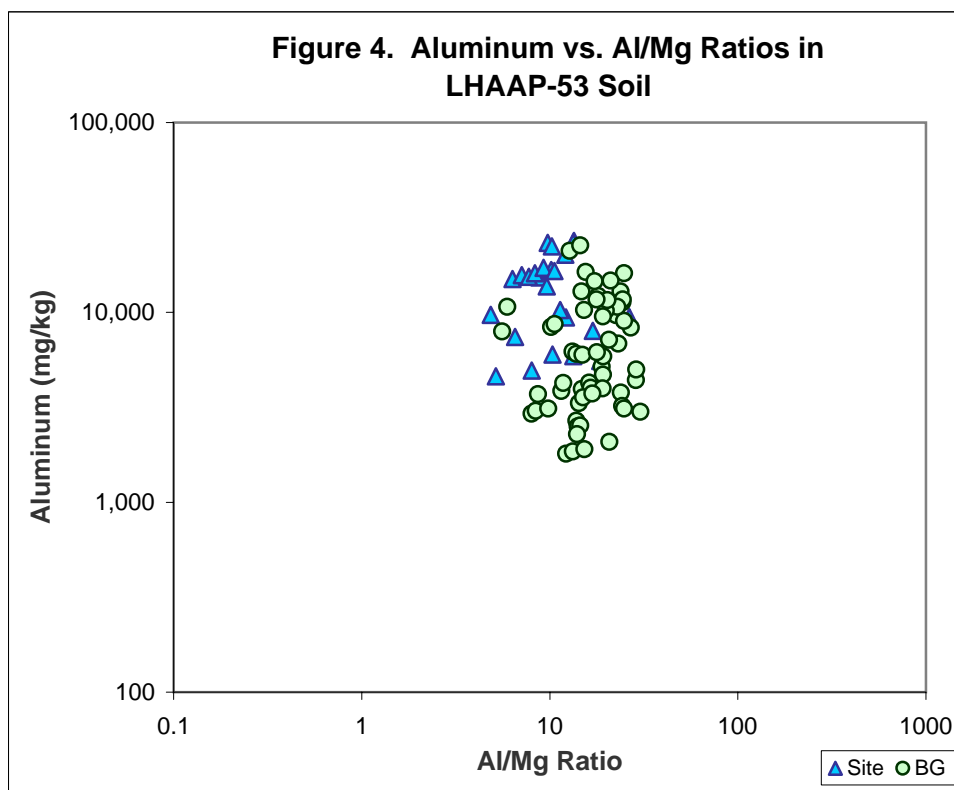
3.0 *References*

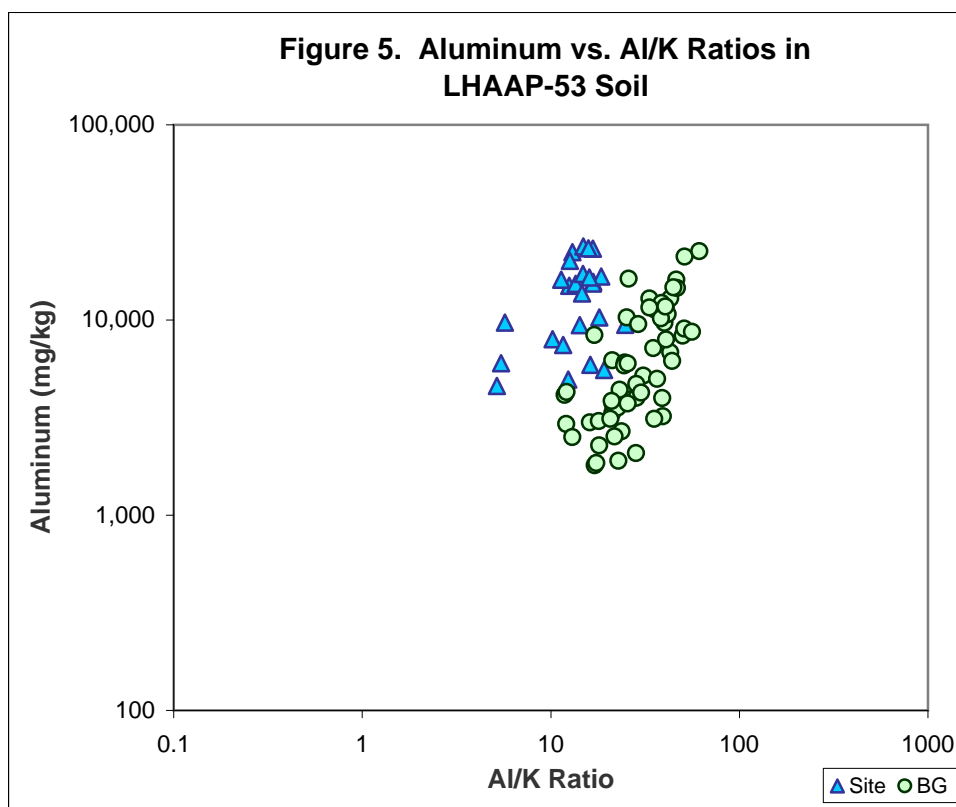
Cornell, R. M. and U. Schwertmann, 2003, *The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses*, Second Edition, Wiley-VCH, Weinheim.

Shaw, 2004, *Background Soil Study Report, Longhorn Army Ammunition Plant, Karnack, Texas*, Final, Houston, Texas, July.

Attachment 2 Figures







Appendix E

***Construction Diagrams for Groundwater Wells at LHAAP-48 and
LHAAP-35C(53)***



Drilling Log

Monitoring Well

00043880
48WW01

Page: 1 of 2

Project Longhorn Army Ammunition Plant Owner Shaw E&I, Inc.
Location Karnack, Texas Proj. No. 845714
Surface Elev. 190.8 ft. Total Hole Depth 53.0 ft. North 6959110.511 East 3314579.818 ft.
Top of Casing 193.24 ft. Water Level Initial 13.0 ft. Static 22.3 ft. Diameter 10 in.
Screen: Dia 4 in. Length 10 ft. Type/Size PVC/0.01 in.
Casing: Dia 4 in. Length 47.42 ft. Type Sch. 40 PVC
Fill Material 20/40 Sand, Bentonite Grout Rig/Core Foremost 5500/5' Core Barrel
Drill Co. ETTL Method Hollow Stem Auger w/Mud Rotary Capabilities
Driller Doug Hines Log By Dale Jayne Date 4/20/04 Driller # NA
Checked By Kay Everett License No. NA

COMMENTS
12" CARBON STEEL SURFACE
CASING SET AT 38' BGS;
APPROXIMATE DIAMETER OF
SECTION 1 BOREHOLE IS 16"
AND SECTION 2 IS 9"

Depth (ft.)	Well Completion	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.	Elevation (ft.)
0						4'x4'x6" Conc. Pad w/ 4" diameter bollards	190.81
		0.0	NA 100%			SILTY CLAY, REDDISH-YELLOW, STIFF, MOIST	190
2		0.0	NA 100%				188
4					CL		186
6		0.0	NA 100%			-BECOMES YELLOW AND LIGHT BLUISH-GRAY IN COLOR	184
8							182
10		0.0	NA 80%		ML	SILT, PALE YELLOW AND BLUISH-GRAY, SOFT, MOIST	180
12					CL	CLAY, YELLOW W/ GRAY, LIGHT BLUISH GRAY MOTTLING	178
14					SP	SAND, BROWNISH-YELLOW, FINE-GRAINED, LOOSE, MOIST	176
16		0.0	NA 100%		CL	CLAY, LIGHT BLUISH GRAY, STIFF, MOIST	174
18					SC	CLAYEY SAND, YELLOW, SOFT, WET	172
20		0.0	NA 100%			CLAY, PALE YELLOW, W/ LIGHT BLUISH-GRAY MOTTLING, STIFF, MOIST	170
22					CL	-BECOMES SATURATED	168
24					SC	CLAYEY SAND, SOFT, SATURATED	166
26		0.0	NA 100%		CL	SANDY CLAY, LIGHT YELLOWISH-BROWN, SOFT, SATURATED	164
28					SC	CLAYEY SAND, YELLOW, LOOSE, SATURATED	162
30		0.0	NA 100%		CL	CLAY, PALE YELLOW, STIFF, SATURATED	
					SC	CLAYEY SAND, SOFT, SATURATED	

Continued Next Page



Drilling Log

Monitoring Well

00043881
48WW01

Page: 2 of 2

Project Longhorn Army Ammunition Plant

Owner Shaw E&I, Inc.

Location Karnack, Texas

Proj. No. 845714

Depth (ft.)	Well Completion	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.	Elevation (ft.)
30						<i>Continued</i> CLAY, LIGHT BLUISH-GREEN, STIFF TO VERY STIFF, WET	160
32		0.0	NA 100%				158
34					CL	-BECOMES PALE YELLOW IN COLOR	156
36		0.0	NA 100%				154
38						NO RECOVERY, DRILLER REPORTS SOFT DRILLING INDICATIVE OF SANDS	152
40		0.0	NA 0%		SP		150
42							148
44		0.0	NA 0%				146
46		0.0	NA 50%		CL	SILTY CLAY, BLUISH GRAY, SOFT, SATURATED	144
48						NO RECOVERY, MOST LIKELY FINE-GRAINED SANDS, THAT WASHED OUT CORE BARREL	142
50		0.0	NA 0%		SP		140
52						HOLE REAMED TO 55'	138
54						END OF BORING	136
56							134
58							132
60							130
62							128
64							126
66							124
68							122
70							

MANCHACA Rev: 10/25/04 SITES 32 50 67 BORING LOGS.GPJ 12/2/04

STATE OF TEXAS WELL REPORT for Tracking #46645

Owner:	Longhorn Army Ammunition Plant	Owner Well #:	48WW01
Address:	Hwy 143 @ Spur 449, LHAAP Karnack, TX 75661	Grid #:	35-24-4
Well Location:	Hwy 143 @ Spur 449 LHAAP Karnack, TX 75661	Latitude:	32° 40' 55" N
Well County:	Harrison	Longitude:	094° 07' 25" W
Elevation:	No Data	GPS Brand Used:	Garmin III Plus

Type of Work:	New Well	Proposed Use:	Monitor
---------------	----------	---------------	---------

Drilling Date: Started: 4/16/2004
Completed: 4/20/2004

Diameter of Hole: Diameter: 16 in From Surface To 38 ft
Diameter: 9 in From 38 ft To 55 ft

Drilling Method: Mud Rotary Hollow Stem Auger

Borehole Completion: Gravel Packed From: 39 ft to 55 ft
Gravel Pack Size: 20/40

Annular Seal Data: 1st Interval: From 0 ft to 38 ft with 19 cement (#sacks and material)
2nd Interval: From 36 ft to 39 ft with 2 bentonite (#sacks and material)
3rd Interval: From 0 ft to 36 ft with 8 cement (#sacks and material)
Method Used: Tremie pipe
Cemented By: Driller
Distance to Septic Field or other Concentrated Contamination: No Data
Distance to Property Line: No Data
Method of Verification: No Data
Approved by Variance: No Data

Surface Completion: Surface Slab Installed

Water Level: Static level: No Data
Artesian flow: No Data

Packers: No Data

Plugging Info: Casing or Cement/Bentonite left in well: No Data

Type Of Pump: No Data

Well Tests: No Data

Water Quality: Type of Water: No Data
Depth of Strata: No Data
Chemical Analysis Made: No Data
Did the driller knowingly penetrate any strata which contained undesirable constituents: No

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.

Company Ettl Engineers & Consultants Inc.

00043883

Information: 1717 E. Erwin
Tyler, TX 75702

Driller License Number: 2126

Licensed Well Driller Signature: Doug Hinds

Registered Driller Apprentice Signature: No Data

Apprentice Registration Number: No Data

Comments: No Data

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner of the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #46645) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft)	To (ft)	Description
0-3		Silty clay - reddish yellow
3-8		Clay - reddish yellow, yellow, gray, & bluish gray
8-12		Silty - yellow & bluish gray
12-13		Clay - yellow, gray, bluish gray
13-14		Sand - brownish yellow
14-16		Clay - bluish gray
16-16.5		Clayey sand - yellow
16.5-23		Clay - yellow & bluish gray
23-24		Clayey sand
24-26		Sandy clay - yellowish brown
26-26.8		Clayey sand
26.8-28		Clay - yellow & bluish gray
28-30		Clayey sand
30-38		Clay - bluish gray & yellow
38-45		Sand
45-47		Silty clay - bluish gray
47-55		Sand

CASING, BLANK PIPE & WELL SCREEN DATA

Dia.	New/Used	Type	Setting From/To
12	New	Carbon Steel	0 - 38
4	New	PVC Sch. 40	0 - 42.6
4	New	PVC Sch. 40 - slotted	42.6 - 52.6 0.010"

HOLE NO. LHS-MW62

DRILLING LOG		DIVISION	SOUTHWEST		INSTALLATION	LHAAP		SHEET	1
1. PROJECT		LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT		8" AUGER		
2. LOCATION (Coordinates or Station)		6959033.70 3314542.70			11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		MSL		
3. DRILLING AGENCY		TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL		FALLING 1500		
4. HOLE NO. (As shown on drawing title and the number)		LHS-MW62			13. OVERBURDEN SAMPLES		DISTURBED		21
5. NAME OF DRILLER		RAY VOIS			14. TOTAL NUMBER CORE BOXES		UNDISTURBED		0
6. DIRECTION OF HOLE		<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER		NOT DETERMINED		
7. THICKNESS OF OVERBURDEN		27.6			16. DATE HOLE		STARTED		09/00/1994
8. DEPTH DRILLED INTO ROCK		0.0			17. ELEVATION TOP OF HOLE		COMPLETED		09/00/1994
9. TOTAL DEPTH OF HOLE		27.6			18. TOTAL CORE RECOVERY FOR BORING		189.0		0.0
					R. PETERSON				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)			
187.0	2		FAT CLAY (CH) (0.0 - 2.0) WITH SAND, YELLOWISH RED, MOIST, SOME GRASS.		J-1	TYPE AUGER ZONE 0.0- 27.6			
						SAMPLE DEPTH			
						J-1 0.0- 2.0			
						J-2 2.0- 4.0			
						J-3 4.0- 7.0			
						J-4 7.0- 8.3			
						J-5 8.3- 9.7			
						J-6 9.7- 12.0			
						J-7 12.0- 13.0			
						J-8 13.0- 14.5			
						J-9 14.5- 16.0			
						J-10 16.0- 16.7			
						J-11 16.7- 18.0			
						J-12 18.0- 19.2			
						J-13 19.2- 19.6			
						J-14 19.6- 20.4			
						J-15 20.4- 21.3			
						J-16 21.3- 22.3			
						J-17 22.3- 23.1			
						J-18 23.4- 23.8			
						J-19 23.8- 24.7			
						J-20 24.7- 25.4			
						J-21 26.4- 27.6			
185.0	4		FAT CLAY (CH) (2.0 - 4.0) DARK YELLOWISH BROWN WITH YELLOWISH RED AND GRAY, THIN LAMINATES, MOIST, SOME GRASS.		J-2				
182.0	6		FAT CLAY (CH) (4.0 - 7.0) WITH SAND, LIGHT GRAY AND YELLOWISH RED, MOIST, LAMINATED		J-3				
180.7	8		LEAN CLAY (CL) (7.0 - 8.3) WITH SAND, LIGHT GRAY AND GRAY, MOIST.		J-4				
179.3	10		LEAN CLAY (CL) (8.3 - 9.7) YELLOWISH BROWN WITH GRAY, WET VERY SILTY.		J-5				
177.0	12		LEAN CLAY (CL) (9.7 - 12.0) SANDY, YELLOWISH RED WITH BROWN, WET, VERY SILTY.		J-6				
176.0	14		LEAN CLAY (CL) (12.0 - 13.0) LIGHT OLIVE BROWN AND LIGHT BROWNISH GRAY, WET, VERY SILTY		J-7				
174.5	16		LEAN CLAY (CL) (13.0 - 14.5) YELLOWISH BROWN AND LIGHT GRAY WITH DARK YELLOWISH BROWN VERY MOIST.		J-8				
173.0	18		LEAN CLAY (CL) (14.5 - 16.0) SANDY, YELLOWISH BROWN WITH TRACE OF GRAY, WET.		J-9				
172.3	20		LEAN CLAY (CL) (16.0 - 16.7) WITH SAND, YELLOWISH BROWN WITH DARK BROWN, MOIST.		J-10				
169.8			LEAN CLAY (CL) (16.7 - 19.2) BROWN AND LIGHT GRAY AND DARK YELLOWISH BROWN, VERY MOIST TO MOIST.		J-11				
169.4			LEAN CLAY (CL) (19.2 - 19.6) LIGHT YELLOWISH BROWN, FREE WATER, VERY SILTY.		J-12				
169.0			LEAN CLAY (CL) (19.6 - 20.4) YELLOW AND LIGHT GRAY, VERY MOIST.		J-13				
					J-14				

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW62

HOLE NO. LHS-MW62

DRILLING LOG		DIVISION	INSTALLATION		SHEET	
		SOUTHWEST	LHAAP		2 of 2 SHEETS	
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6959033.70 3314542.70			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FALLING 1500			
4. HOLE NO. (As shown on drawing title and the number) LHS-MW62			13. OVERBURDEN SAMPLES DISTURBED 21 UNDISTURBED 0			
5. NAME OF DRILLER RAY VOIS			14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER NOT DETERMINED			
7. THICKNESS OF OVERBURDEN 27.6			16. DATE HOLE STARTED 09/00/1994 COMPLETED 09/00/1994			
8. DEPTH DRILLED INTO ROCK 0.0			17. ELEVATION TOP OF HOLE 189.0			
9. TOTAL DEPTH OF HOLE 27.6			18. TOTAL CORE RECOVERY FOR BORING 0.0 %			
R. PETERSON						
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
168.6			LEAN CLAY (CL) (19.6 - 20.4) YELLOW AND LIGHT GRAY, VERY MOIST.		J-14	
			LEAN CLAY (CL) (20.4 - 21.3) CL-ML, SILTY CLAY WITH SAND, YELLOWISH BROWN AND LIGHT GRAY, WET.		J-15	
167.7			LEAN CLAY (CL) (21.3 - 22.3) YELLOWISH BROWN WITH DARK YELLOWISH BROWN, VERY MOIST.		J-16	
166.7	22		LEAN CLAY (CL) (22.3 - 23.1) CL-ML, SILTY CLAY WITH SAND, YELLOWISH BROWN WITH LIGHT GRAY, FREE WATER.		J-17	
165.9			LEAN CLAY (CL) (23.1 - 23.8) SANDY SILTY CLAY, YELLOWISH BROWN WITH DARK YELLOW, WET.		J-18	
165.2	24		LEAN CLAY (CL) (23.8 - 24.7) WITH SAND, LIGHT OLIVE BROWN AND LIGHT GRAY, VERY MOIST.		J-19	
164.3			LEAN CLAY (CL) (24.7 - 26.4) CL-ML, SILTY CLAY WITH SAND, YELLOWISH BROWN WITH LIGHT GRAY AND DARK YELLOWISH BROWN, WET.		J-20	
162.6	26		LEAN CLAY (CL) (26.4 - 27.6) LIGHT GRAY AND LIGHT BROWNISH GRAY, VERY MOIST.		J-21	
161.4						
	28					
	30					
	32					
	34					
	36					
	38					
	40					
PROJECT LHAAP-WASTE SUMPS				HOLE NO. LHS-MW62		

WELL NO. LHS-MW62

MONITORING WELL SHEET

PROJECT & INSTALLATION:

LONGHORN ARMY AMMUNITION PLANT - SUMPS

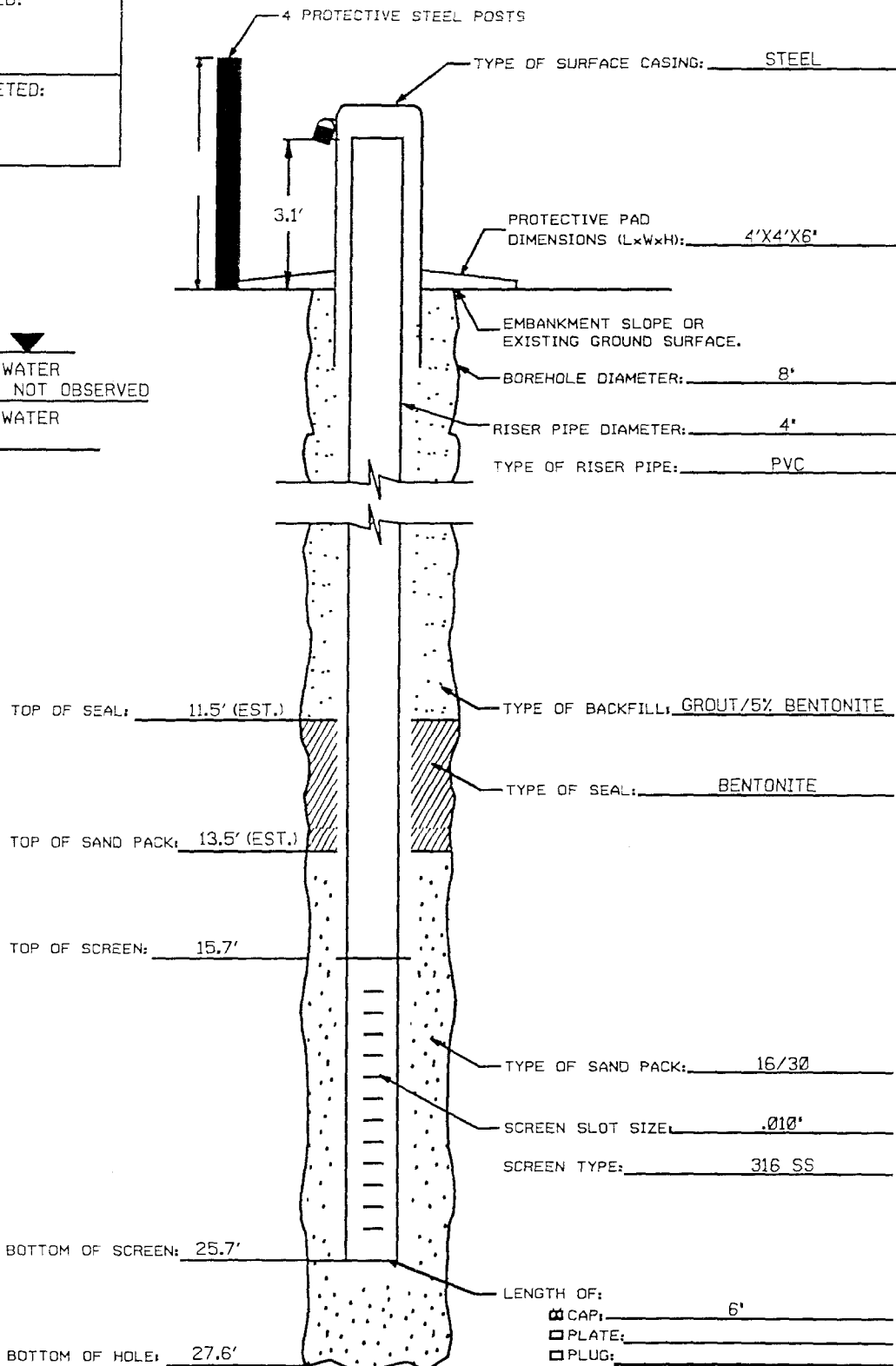
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994

GROUNDWATER
DEPTH: NOT OBSERVED
GROUNDWATER
DATE: _____



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW63

DRILLING LOG		DIVISION	SOUTHWEST		INSTALLATION	LHAAP		SHEET	1
1. PROJECT		LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT		8" AUGER		
2. LOCATION (County, State or Station)		6939185.00 3314366.40			11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		MSL		
3. DRILLING AGENCY		TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL		FALLING 1500		
4. HOLE NO. (As shown on drawing title and the number)		LHS-MW63			13. OVERBURDEN SAMPLES		DISTURBED	12	UNDISTURBED
5. NAME OF DRILLER		RAY VOIS			14. TOTAL NUMBER CORE BOXES		0		
6. DIRECTION OF HOLE		<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER		NOT DETERMINED		
7. THICKNESS OF OVERBURDEN		20.0			16. DATE HOLE		STARTED	09/00/1994	COMPLETED
8. DEPTH DRILLED INTO ROCK		0.0			17. ELEVATION TOP OF HOLE		190.9		
9. TOTAL DEPTH OF HOLE		20.0			18. TOTAL CORE RECOVERY FOR BORING		0.0 %		
					R. PETERSON				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)			
188.9	2		LEAN CLAY (CL) (0.0 - 2.0) YELLOWISH BROWN AND STRONG BROWN, DAMP.		J-1	TYPE ZONE AUGER 0.0- 20.0			
186.9	4		LEAN CLAY (CL) (2.0 - 4.0) STRONG BROWN AND DARK YELLOWISH BROWN WITH GRAY, MOIST.		J-2	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 4.0 J-3 4.0- 6.5 J-4 6.5- 7.8 J-5 7.8- 11.0 J-6 11.0- 13.2 J-7 13.2- 14.5 J-8 14.5- 15.2 J-9 15.2- 16.5 J-10 16.5- 17.5 J-11 17.5- 18.2 J-12 18.2- 20.0			
184.4	6		FAT CLAY (CH) (4.0 - 6.5) YELLOWISH BROWN, MOIST.		J-3				
183.1	8		LEAN CLAY (CL) (6.5 - 7.8) WITH SAND, DARK BROWN AND LIGHT GRAY, MOIST, LAMINATED.		J-4				
179.9	10		LEAN CLAY (CL) (7.8 - 11.0) SANDY, YELLOWISH BROWN AND LIGHT GRAY, MOIST, LAMINATED.		J-5				
177.7	12		LEAN CLAY (CL) (11.0 - 13.2) WITH SAND, YELLOWISH BROWN WITH LIGHT GRAY, VERY MOIST.		J-6				
176.4	14		SILT SAND (SM) (13.2 - 14.5) STRONG BROWN WITH YELLOWISH BROWN AND GRAY, FREE WATER.		J-7				
174.4	16		FAT CLAY (CH) (14.5 - 16.5) YELLOWISH RED WITH YELLOWISH BROWN AND GRAY TO LIGHT GRAY AND DARK YELLOWISH BROWN MOTTLED, MOIST.		J-8				
173.4	18		CLAY SAND (SC) (16.5 - 17.5) SC-SM, SILTY CLAYEY SAND, LIGHT GRAY AND YELLOWISH BROWN WET.		J-9				
170.9	20		LEAN CLAY (CL) (17.5 - 20.0) DARK YELLOWISH BROWN WITH LIGHT GRAY TO LIGHT GRAY WITH BLACK AND DARK YELLOWISH BROWN VERY MOIST TO MOIST.		J-10				
					J-11				
					J-12				

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW63

00043888

WELL NO. LHS-MW63

MONITORING WELL SHEET

PROJECT & INSTALLATION:

LONGHORN ARMY AMMUNITION PLANT - SUMPS

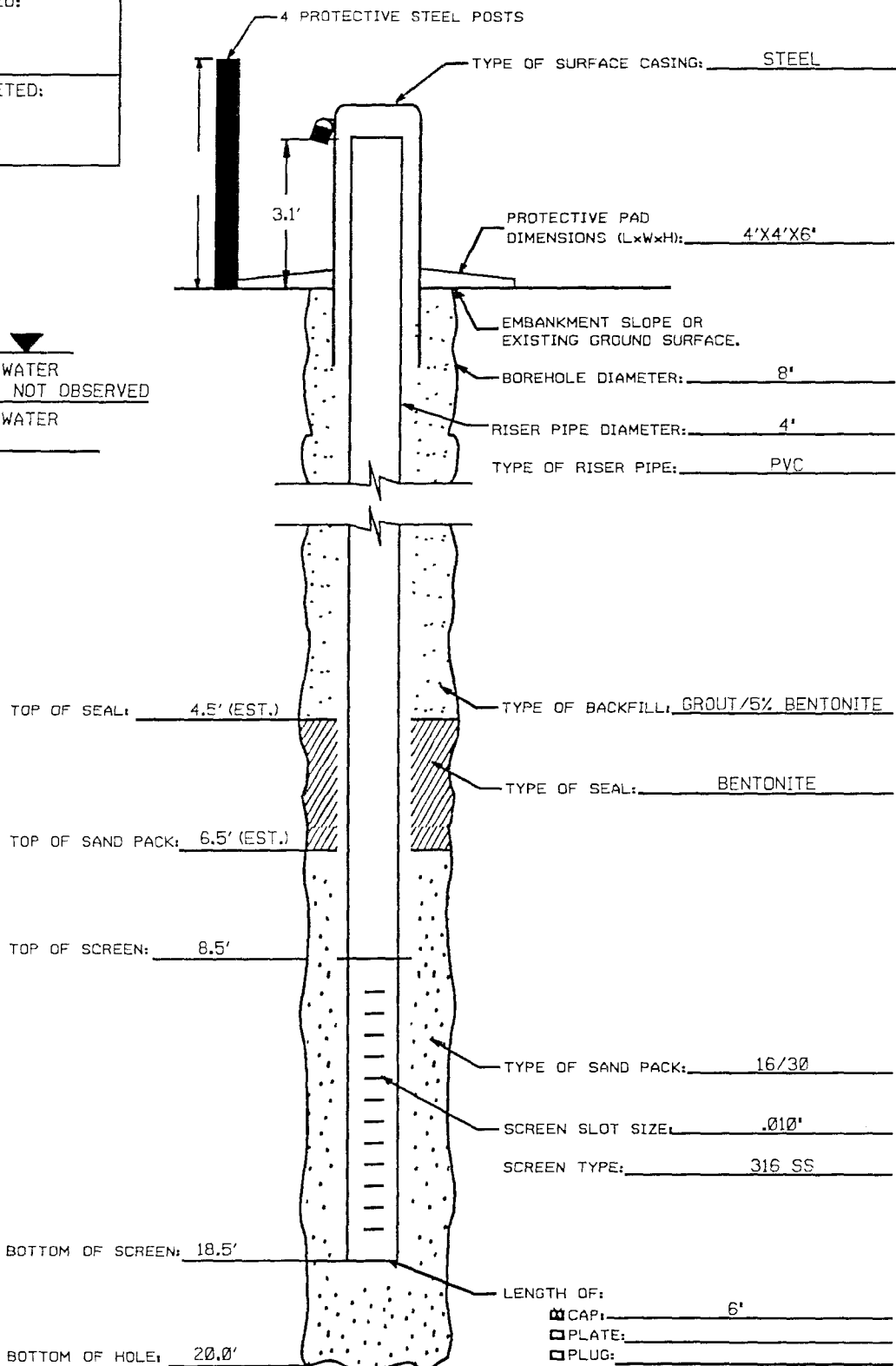
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994

GROUNDWATER
DEPTH: NOT OBSERVED
GROUNDWATER
DATE: _____



INSPECTOR:

RICHARD PETERSON

PROJECT	HOLE NO.
LHAAP--WASTE SUMPS	LHS-MWS4

HOLE NO. LHS-MW64

DRILLING LOG		DIVISION	SOUTHWEST		INSTALLATION	LHAAP		SHEET	2
1. PROJECT		LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT		8" AUGER		
2. LOCATION (Coordinates or Station)		6959088.90 3314916.70			11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		MSL		
3. DRILLING AGENCY		TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL		FALLING 1500		
4. HOLE NO. (As shown on drawing title and file number)		LHS-MW64			13. OVERBURDEN SAMPLES		DISTURBED	16	UNDISTURBED
5. NAME OF DRILLER		RAY VOILS			14. TOTAL NUMBER CORE BOXES		0		
6. DIRECTION OF HOLE		<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER		NOT DETERMINED		
7. THICKNESS OF OVERBURDEN		25.0			16. DATE HOLE		STARTED	09/00/1994	COMPLETED
8. DEPTH DRILLED INTO ROCK		0.0			17. ELEVATION TOP OF HOLE		188.2		
9. TOTAL DEPTH OF HOLE		25.0			18. TOTAL CORE RECOVERY FOR BORING		0.0 %		
					R. PETERSON				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)			
167.8			SILT SAND (SM) (19.0 - 20.4)		J-13				
			YELLOWISH BROWN, FREE WATER.		J-14				
166.9			LEAN CLAY (CL) (20.4 - 21.3)						
			WITH SAND, DARK YELLOWISH BROWN, WET, LIGHT GRAY LENSES.						
	22		LEAN CLAY (CL) (21.3 - 23.2)		J-15				
			DARK YELLOWISH BROWN AND BROWN, VERY MOIST.						
165.0			FAT CLAY (CH) (23.2 - 25.0)		J-16				
	24		GRAYISH BROWN, MOIST, SOME IRON-OXIDE STAINS.						
163.2									
	26								
	28								
	30								
	32								
	34								
	36								
	38								
	40								

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW64

WELL NO. LHS-MW64

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

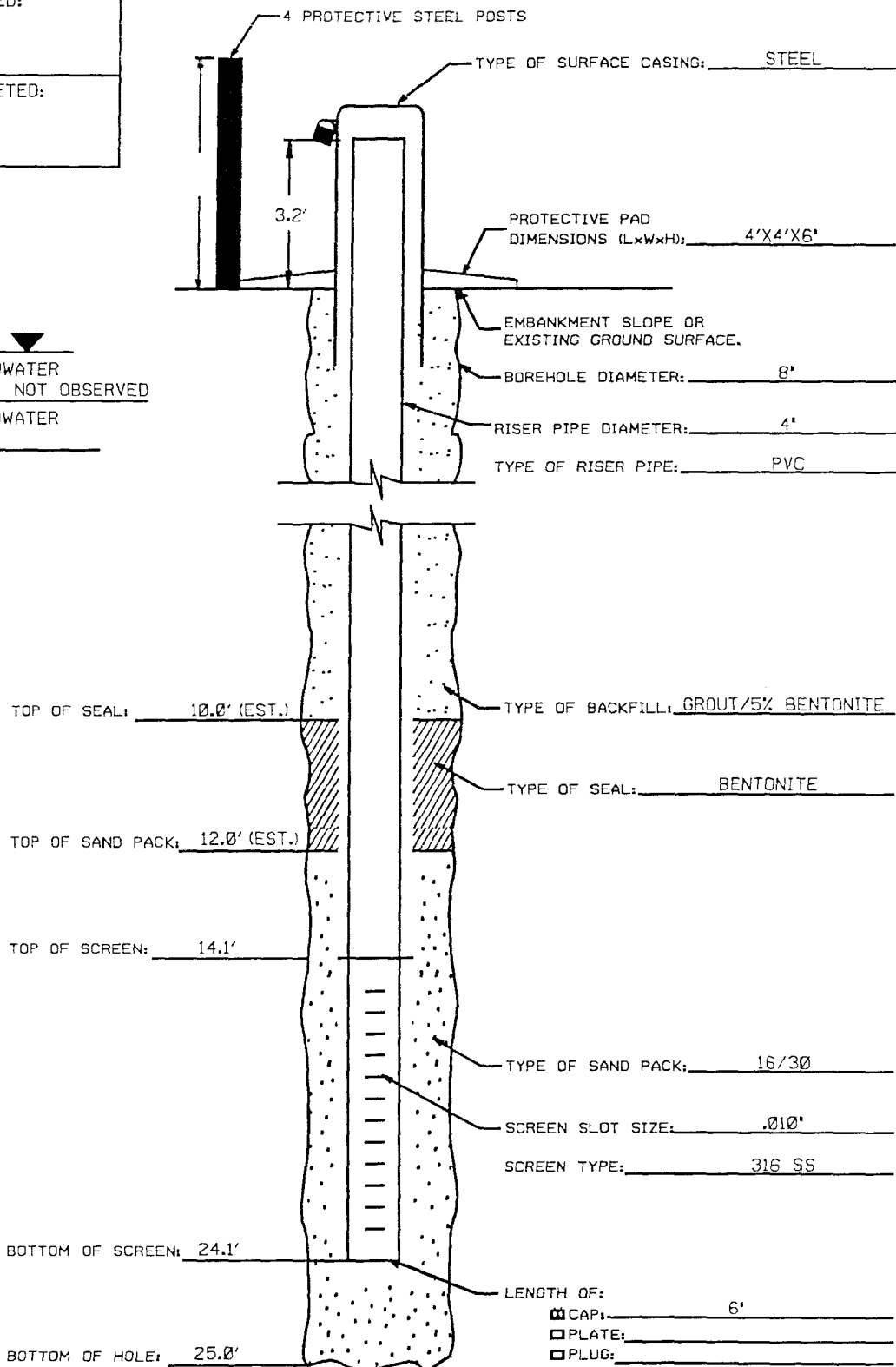
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE: _____



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW65

DRILLING LOG		DIVISION	INSTALLATION	SHEET		
		SOUTHWEST	LHAAP	1 OF 1 SHEETS		
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6959263.20 3314967.70			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FALLING 1500			
4. HOLE NO. (As shown on drawing title and file number) LHS-MW65			13. OVERBURDEN SAMPLES DISTURBED 8 UNDISTURBED 0			
5. NAME OF DRILLER RAY VOIS			14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER NOT DETERMINED			
7. THICKNESS OF OVERBURDEN 18.0			16. DATE HOLE STARTED 09/00/1994 COMPLETED 09/00/1994			
8. DEPTH DRILLED INTO ROCK 0.0			17. ELEVATION TOP OF HOLE 191.7			
9. TOTAL DEPTH OF HOLE 18.0			18. TOTAL CORE RECOVERY FOR BORING 0.0 x			
R. PETERSON						
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
						TYPE ZONE AUGER 0.0- 18.0
	2		LEAN CLAY (CL) (0.0 - 4.0) WITH SAND, DARK YELLOWISH BROWN WITH YELLOWISH RED, LIGHT GRAY AND RED LAMINATIONS AND CLAY CLUMPS IN BOTTOM HALF OF SAMPLE, MOIST, SILTY IN UPPER HALF OF SAMPLE.		J-1	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 4.0 J-3 4.0- 9.5 J-4 9.5- 10.3 J-5 10.3- 12.7 J-6 12.7- 15.3 J-7 15.3- 17.0 J-8 17.0- 18.0
187.7	4		LEAN CLAY (CL) (4.0 - 9.5) YELLOWISH BROWN AND LIGHT BROWNISH GRAY, MOIST.		J-2	
	6				J-3	
	8					
182.2	10		LEAN CLAY (CL) (9.5 - 10.3) WITH SAND, YELLOWISH BROWN AND LIGHT GRAY, MOIST, LAMINATED SILTY CLAY.		J-4	
181.4	12		SILT SAND (SM) (10.3 - 15.3) YELLOWISH BROWN TO DARK YELLOWISH BROWN AND RED AND LIGHT BROWN, DAMP TO VERY MOIST.		J-5	
	14				J-6	
176.4	16		FAT CLAY (CH) (15.3 - 18.0) YELLOWISH BROWN AND LIGHT GRAY TO LIGHT BROWNISH GRAY WITH YELLOWISH BROWN, MOIST.		J-7	
	18				J-8	
173.7	20					

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW65

WELL NO. LHS-MW65

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

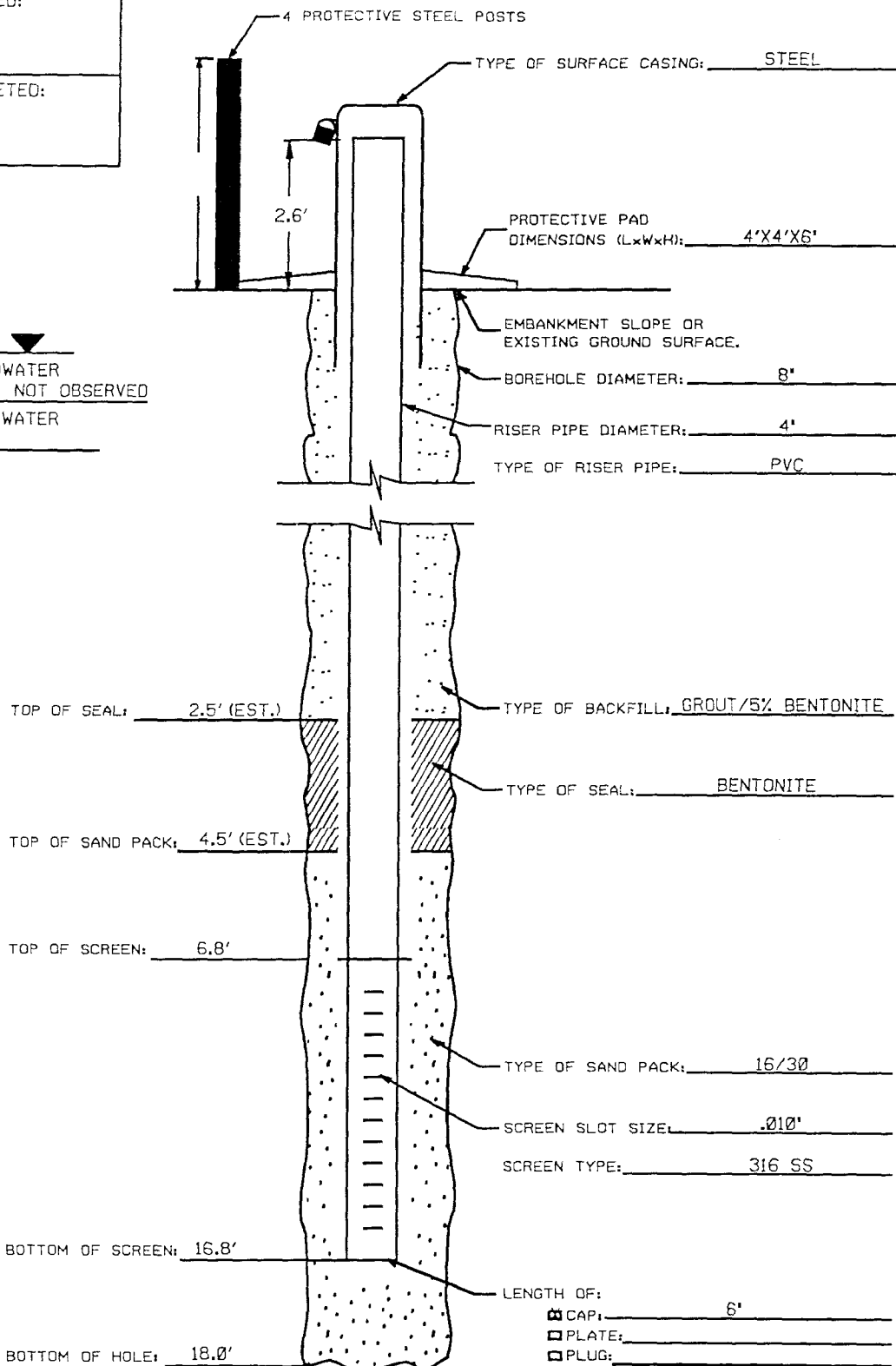
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE: _____



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW66

DRILLING LOG		DIVISION	SOUTHWEST		INSTALLATION	LHAAP		SHEET	1
1. PROJECT		LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT		8" AUGER		
2. LOCATION (Coordinates or Station)		6959501.40 3314813.50			11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		MSL		
3. DRILLING AGENCY		TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL		FALLING 1500		
4. HOLE NO. (As shown on drawing title and file number)		LHS-MW66			13. OVERBURDEN SAMPLES		DISTURBED	7	UNDISTURBED
5. NAME OF DRILLER		RAY VOIS			14. TOTAL NUMBER CORE BOXES		0		
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.					15. ELEVATION GROUND WATER		NOT DETERMINED		
7. THICKNESS OF OVERBURDEN		18.0			16. DATE HOLE		STARTED	09/00/1994	COMPLETED
8. DEPTH DRILLED INTO ROCK		0.0			17. ELEVATION TOP OF HOLE		192.1		
9. TOTAL DEPTH OF HOLE		18.0			18. TOTAL CORE RECOVERY FOR BORING		0.0 %		
					R. PETERSON				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)			
190.1	2		LEAN CLAY (CL) (0.0 - 2.0) SANDY, YELLOWISH BROWN WITH STRONG BROWN, DAMP, SOME GRASS.		J-1	TYPE ZONE AUGER 0.0- 18.0			
188.1	4		LEAN CLAY (CL) (2.0 - 4.0) WITH SAND, DARK YELLOWISH BROWN DAMP, SOME LIGHT GRAY AND RED LAMINATED CLAY CLUMPS.		J-2	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 4.0 J-3 4.0- 9.0 J-4 9.0- 10.5 J-5 10.5- 12.5 J-6 12.5- 16.5 J-7 16.5- 18.0			
183.1	6		FAT CLAY (CH) (4.0 - 9.0) YELLOWISH BROWN WITH LIGHT GRAY, MOIST.		J-3				
179.6	10		LEAN CLAY (CL) (9.0 - 12.5) WITH SAND, LIGHT GRAY WITH BROWN WITH BLACK TO DARK YELLOWISH BROWN AND LIGHT GRAY, MOIST, SILTY IN BOTTOM HALF OF SAMPLE.		J-4				
175.6	12		CLAY SAND (SC) (12.5 - 16.5) DARK YELLOWISH BROWN WITH BROWN, WET.		J-5				
174.1	14		FAT CLAY (CH) (16.5 - 18.0) LIGHT GRAY WITH YELLOWISH BROWN, MOIST.		J-6				
	16				J-7				
	18								
	20								

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW66

WELL NO. LHS-MW66

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

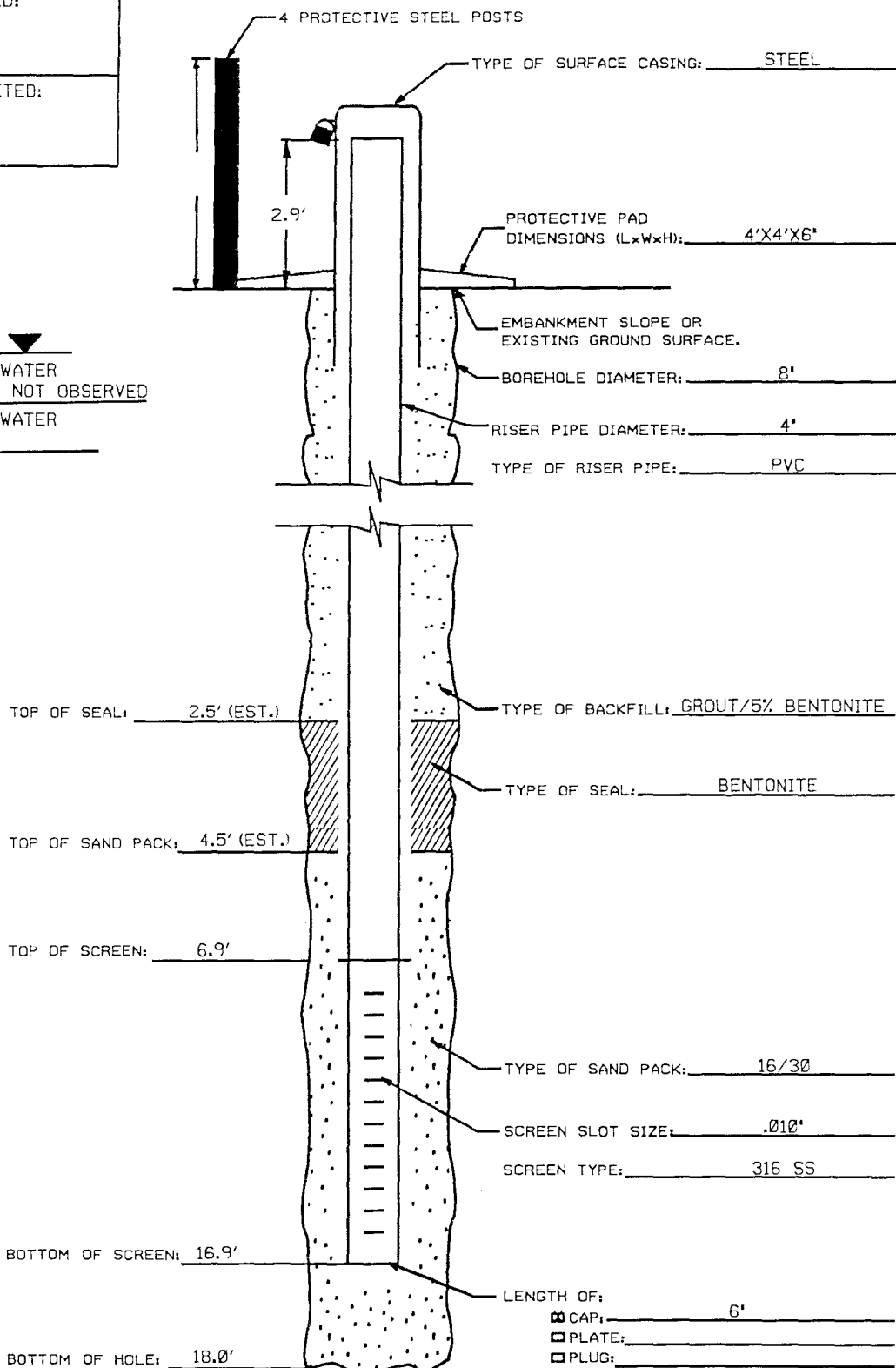
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE: _____



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW67

DRILLING LOG		DIVISION	INSTALLATION		SHEET	
		SOUTHWEST	LHAAP		1 OF 1 SHEETS	
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6957355.20 3315705.60			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FALLING 1500/CME 75			
4. HOLE NO. (As shown on drawing title and file number) LHS-MW67			13. OVERBURDEN SAMPLES		DISTURBED 8 UNDISTURBED 0	
5. NAME OF DRILLER TOM BEAVERS			14. TOTAL NUMBER CORE BOXES		0	
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER SEE REMARKS			
7. THICKNESS OF OVERBURDEN 20.0			16. DATE HOLE		STARTED 09/23/1994 COMPLETED 09/23/1994	
8. DEPTH DRILLED INTO ROCK 0.0			17. ELEVATION TOP OF HOLE		182.6	
9. TOTAL DEPTH OF HOLE 20.0			18. TOTAL CORE RECOVERY FOR BORING		0.0 %	
CHARLIE TRANSUE						
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
			LEAN CLAY (CL) (0.0 - 3.5) YELLOWISH BROWN, MOIST.			WATER ENCOUNTERED @ 11.5' USED 10" HOLLOWSTEM AUGER TO SET WELL. SAMPLE TYPE ZONE AUGER 0.0 - 11.0 SPLITSPOON 11.0 - 16.0 AUGER 16.0 - 20.0
179.1	4		LEAN CLAY (CL) (3.5 - 9.0) SANDY, DARK YELLOWISH BROWN TO LIGHT BROWN, MOIST TO VERY MOIST.		J-1	
	6				J-2	SAMPLE DEPTH J-1 2.0 - 3.0 J-2 4.0 - 5.0 J-3 7.0 - 8.0 J-4 10.5 - 11.0 J-5 13.0 - 13.4 J-6 13.4 - 14.0 J-7 15.0 - 16.0 J-8 18.0 - 20.0
	8				J-3	
173.6	10		LEAN CLAY (CL) (9.0 - 13.4) DARK YELLOWISH BROWN WITH LIGHT GRAY, MOIST TO VERY MOIST.		J-4	
	12				J-5	
169.2	14		SILT SAND (SM) (13.4 - 14.5) DARK YELLOWISH BROWN, WET.		J-6	
168.1	16		CLAY SAND (SC) (14.5 - 17.0) MOTTLED LIGHT BROWNISH GRAY AND YELLOWISH BROWN, WET.		J-7	
165.6	18		LEAN CLAY (CL) (17.0 - 20.0) MOTTLED LIGHT GRAY AND DARK YELLOWISH BROWN, VERY MOIST.		J-8	
162.6	20					
PROJECT LHAAP-WASTE SUMPS				HOLE NO. LHS-MW67		

WELL NO. LHS-MW67

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

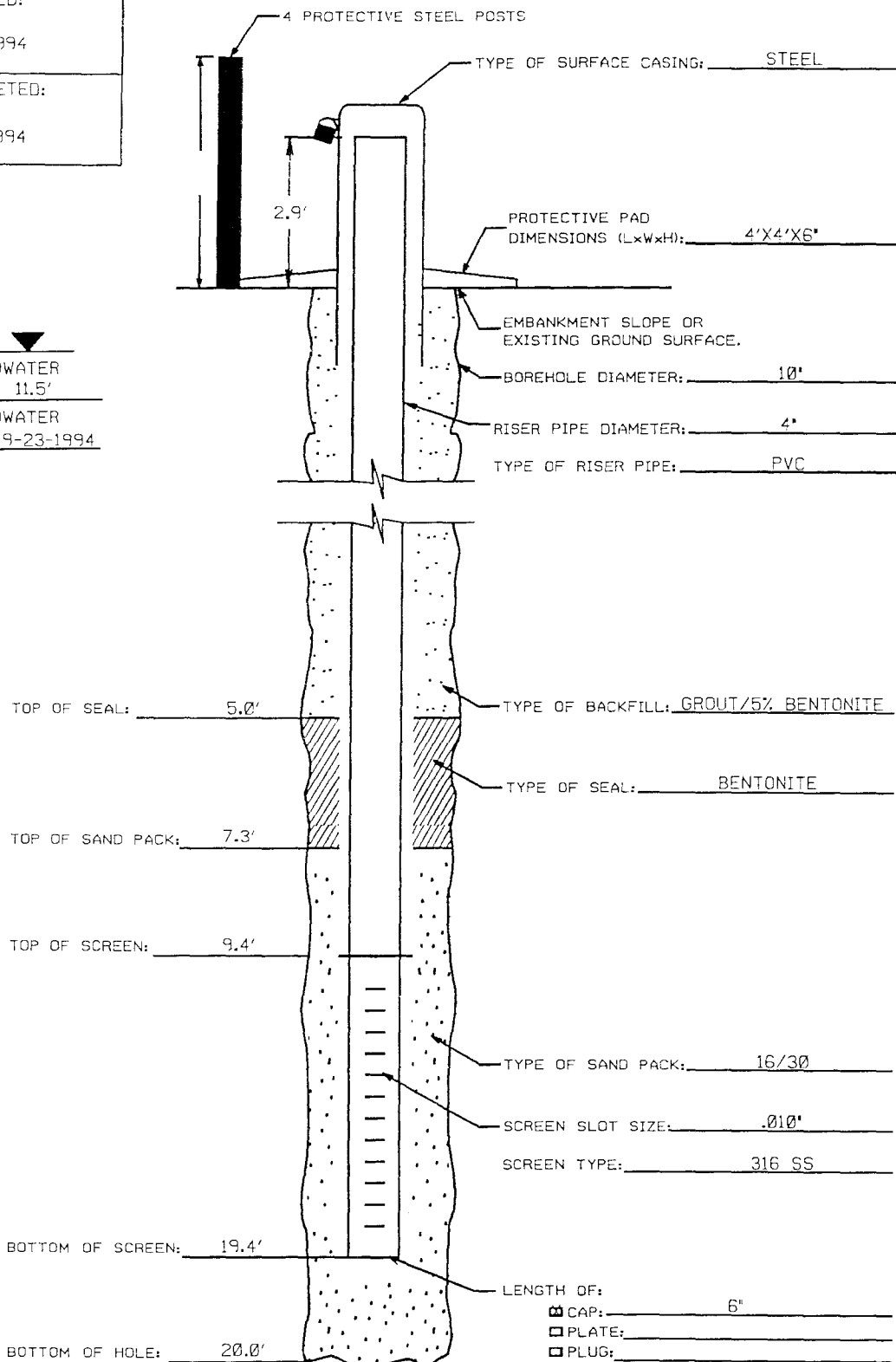
DATE STARTED:

9-23-1994

DATE COMPLETED:

9-23-1994


 GROUNDWATER
 DEPTH: 11.5'
 GROUNDWATER
 DATE: 9-23-1994



INSPECTOR:

CHARLIE TRANSUE

HOLE NO. LHS-MW68

DRILLING LOG		DIVISION	INSTALLATION	SHEET		
		SOUTHWEST	LHAAP	1 OF 1 SHEETS		
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6957113.20 3315492.40			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500			
4. HOLE NO. (As shown on drawing title and the number) LHS-MW68			13. OVERBURDEN SAMPLES DISTURBED 13 UNDISTURBED 0			
5. NAME OF DRILLER RAY VOIS			14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER NOT DETERMINED			
7. THICKNESS OF OVERBURDEN 22.0			16. DATE HOLE STARTED 09/00/1994 COMPLETED 09/00/1994			
8. DEPTH DRILLED INTO ROCK 0.0			17. ELEVATION TOP OF HOLE 186.5			
9. TOTAL DEPTH OF HOLE 22.0			18. TOTAL CORE RECOVERY FOR BORING 0.0 %			
R. PETERSON						
ELEVATION e	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV- ERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
184.5			LEAN CLAY (CL) (0.0 - 2.0) WITH SAND, DARK YELLOWISH BROWN, DAMP.		J-1	TYPE ZONE AUGER 0.0- 22.0
182.5	3		LEAN CLAY (CL) (2.0 - 4.0) SANDY, STRONG BROWN, DAMP.		J-2	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 4.0 J-3 4.0- 7.0 J-4 7.0- 9.0 J-5 9.0- 11.0 J-6 11.0- 13.0 J-7 13.0- 13.7 J-8 13.7- 15.1 J-9 15.1- 15.7 J-10 15.7- 17.4 J-11 17.4- 18.0 J-12 18.0- 20.5 J-13 20.5- 22.0
177.5	6		LEAN CLAY (CL) (4.0 - 9.0) WITH SAND, YELLOWISH RED WITH DARK RED TO YELLOWISH BROWN WITH LIGHT GRAY AND YELLOWISH RED, MOIST.		J-3	
175.5	9		CLAY SAND (SC) (9.0 - 11.0) SC-SM, SILTY CLAYEY SAND, YELLOWISH BROWN WITH STRONG BROWN, MOIST.		J-4	
173.5	12		SILT SAND (SM) (11.0 - 13.0) YELLOWISH BROWN, WET.		J-5	
172.8			LEAN CLAY (CL) (13.0 - 13.7) YELLOWISH BROWN WITH DARK YELLOWISH BROWN AND GRAY, MOIST.		J-6	
171.4	15		SILT SAND (SM) (13.7 - 15.1) YELLOWISH BROWN, FREE WATER.		J-7	
170.8			LEAN CLAY (CL) (15.1 - 15.7) WITH SAND, MOTTLED DARK YELLOWISH BROWN AND GRAY, MOIST.		J-8	
169.1			SILT SAND (SM) (15.7 - 17.4) YELLOWISH BROWN, FREE WATER.		J-9	
168.5	18		LEAN CLAY (CL) (17.4 - 18.0) WITH SAND, YELLOWISH BROWN, MOIST.		J-10	
166.0			SILT SAND (SM) (18.0 - 20.5) YELLOWISH BROWN, FREE WATER.		J-11	
164.5	21		FAT CLAY (CH) (20.5 - 22.0) LIGHT BROWNISH GRAY WITH RUST, MOIST.		J-12	
	24				J-13	
	27					
	30					

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW68

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

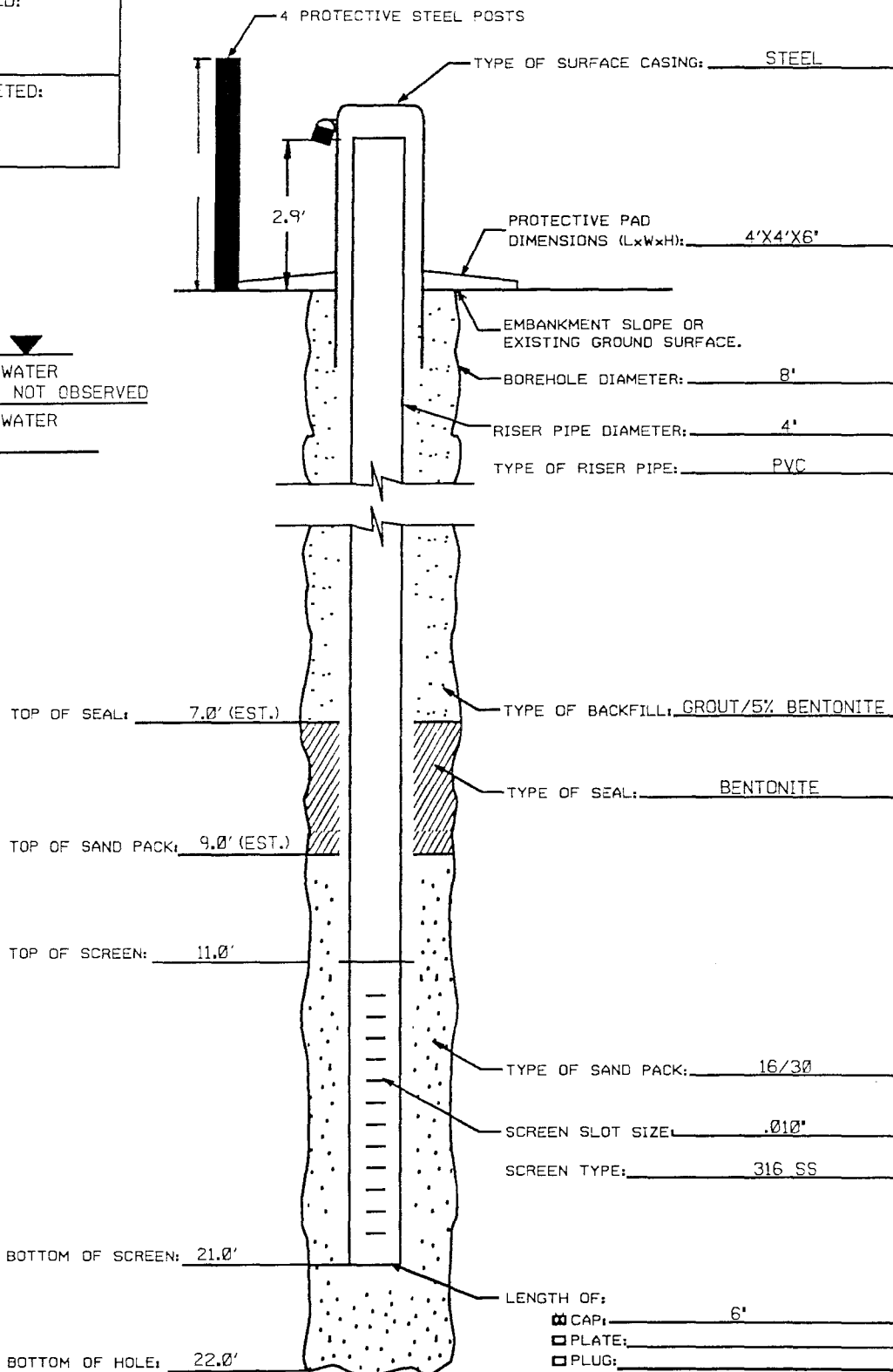
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE: _____



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW69

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
		SOUTHWEST		LHAAP		1 OF 2 SHEETS	
1. PROJECT LHAAP-WASTE SUMPS				10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6957345.30 3315272.10				11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE				12. MANUFACTURER'S DESIGNATION OF DRILL CME 75			
4. HOLE NO. (As shown on drawing title and file number) LHS-MW69				13. OVERBURDEN SAMPLES		DISTURBED 13 UNDISTURBED 0	
5. NAME OF DRILLER TOM BEAVERS				14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.				15. ELEVATION GROUND WATER SEE REMARKS			
7. THICKNESS OF OVERBURDEN 51.0				16. DATE HOLE		STARTED 09/27/1994 COMPLETED 09/28/1994	
8. DEPTH DRILLED INTO ROCK 0.0				17. ELEVATION TOP OF HOLE 180.4			
9. TOTAL DEPTH OF HOLE 51.0				18. TOTAL CORE RECOVERY FOR BORING 0.0 x			
				CHARLIE TRANSUE			
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)	
176.9	3		LEAN CLAY (CL) (0.0 - 3.5) REDDISH BROWN, MOIST.			WATER ENCOUNTERED @ 5.0'	
173.9	6		LEAN CLAY (CL) (3.5 - 6.5) WITH SAND, DARK YELLOWISH BROWN, MOIST TO WET, 5.5'-6.0': GRAY CLAY LENSES.		J-1	USED 10" HOLLOWSTEM AUGER TO SET WELL.	
170.2	9		LEAN CLAY (CL) (6.5 - 10.2) MOTTLED YELLOWISH BROWN AND GRAY WITH BLACK AND RED, MOIST.		J-2	SAMPLE TYPE ZONE	
167.2	12		SILT (ML) (10.2 - 13.2) SANDY, MOTTLED YELLOWISH BROWN AND LIGHT GRAY WITH GRAY CLAY LENSES, MOIST.		J-3	AUGER 0.0- 8.0 SPLITSPOON 8.0- 25.0 AUGER 25.0- 51.0	
159.1	15		SILT SAND (SM) (13.2 - 21.3) GRAY, WET TO FREE WATER.		J-4	SAMPLE DEPTH	
155.4	18		CLAY SAND (SC) (21.3 - 25.0) SC-SM, SILTY, MOTTLED YELLOWISH BROWN AND GRAY, WET.		J-5	J-1 4.0- 5.0 J-2 5.5- 6.0 J-3 7.0- 8.0 J-4 9.0- 10.0 J-5 10.5- 11.5 J-6 15.0- 16.0 J-7 19.5- 20.0 J-8 22.6- 23.1 J-9 27.0- 28.0 J-10 33.5- 34.0 J-11 40.5- 41.0 J-12 48.0- 49.0 J-13 49.0- 51.0	
150.4	21		SILT SAND (SM) (25.0 - 30.7) MOTTLED BROWNISH YELLOW AND GRAY, FREE WATER.		J-6		
	24				J-7		
	27				J-8		
	30				J-9		

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW69

HOLE NO. LHS-MW69

DRILLING LOG		DIVISION	INSTALLATION		SHEET	
		SOUTHWEST	LHAAP		2	
1. PROJECT		10. SIZE AND TYPE OF BIT		2 SHEETS		
LHAAP-WASTE SUMPS		8" AUGER				
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)				
6857345.30		3315272.10		MSL		
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL				
TULSA DISTRICT COE		CME 75				
4. HOLE NO. (As shown on drawing title and file number)		13. OVERBURDEN SAMPLES		DISTURBED 13 UNDISTURBED 0		
LHS-MW69		14. TOTAL NUMBER CORE BOXES		0		
5. NAME OF DRILLER		15. ELEVATION GROUND WATER		SEE REMARKS		
TOM BEAVERS		16. DATE HOLE		STARTED 09/27/1994 COMPLETED 09/28/1994		
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.		17. ELEVATION TOP OF HOLE		180.4		
7. THICKNESS OF OVERBURDEN 51.0		18. TOTAL CORE RECOVERY FOR BORING		0.0 %		
8. DEPTH DRILLED INTO ROCK 0.0						
9. TOTAL DEPTH OF HOLE 51.0		CHARLIE TRANSUE				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
a	b	c	d	e	f	g
149.7			SILT SAND (SM) (25.0 - 30.7)			
			SAND (SP) (30.7 - 44.0)			
			SP-SM, WITH SILT, YELLOW TO YELLOWISH BROWN, FREE WATER.			
	33				J-10	
	36					
	39				J-11	
	42					
136.4			CLAY SAND (SC) (44.0 - 51.0)			
	45		ZONED DARK YELLOWISH BROWN AND LIGHT GRAY, VERY MOIST.			
	48				J-12	
	51				J-13	
129.4						
	54					
	57					
	60					

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW69

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

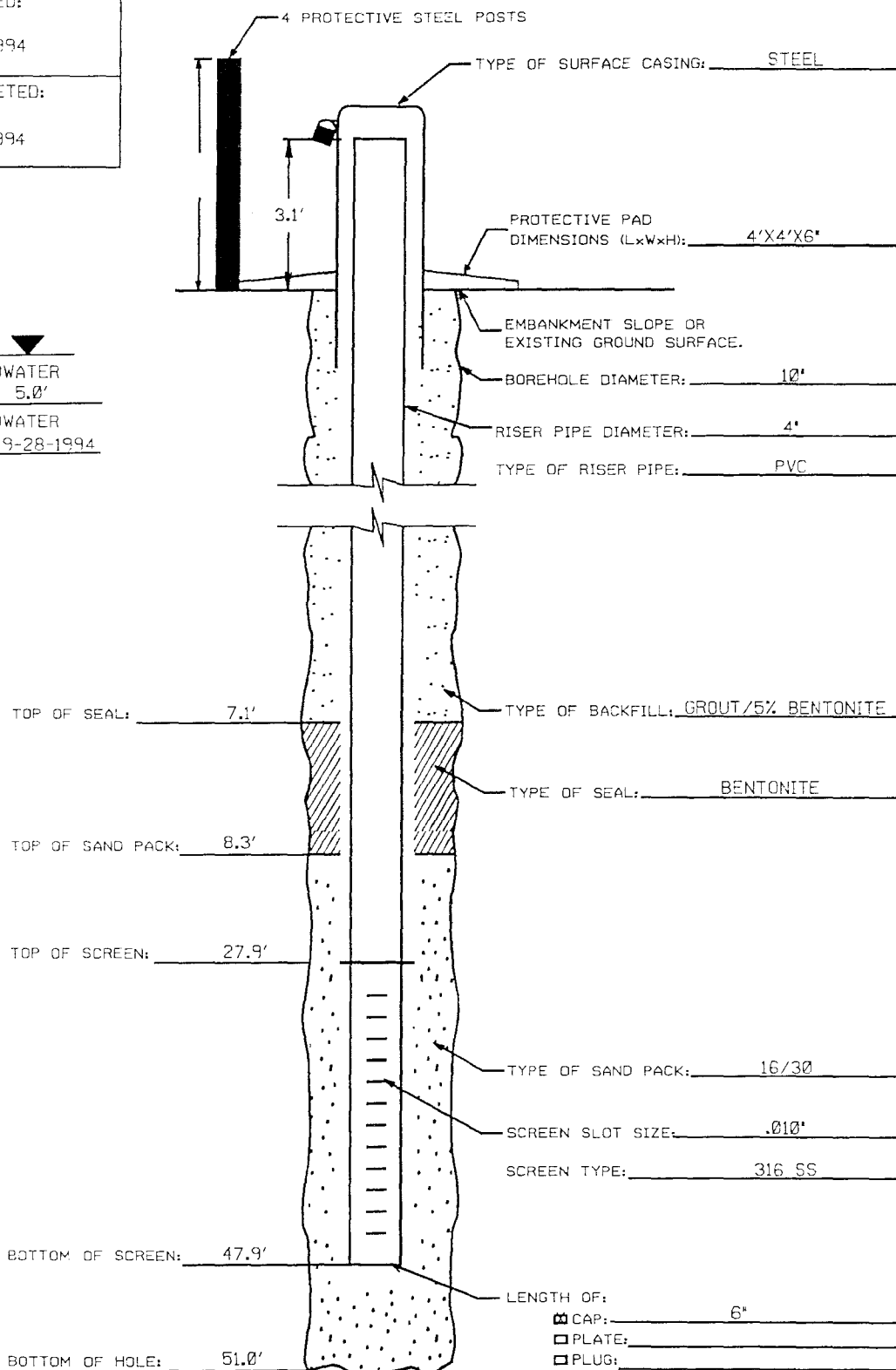
DATE STARTED:

9-27-1994

DATE COMPLETED:

9-28-1994


 GROUNDWATER
 DEPTH: 5.0'
 GROUNDWATER
 DATE: 9-28-1994



INSPECTOR:

CHARLIE TRANSUE

HOLE NO. LHS-MW70

DRILLING LOG		DIVISION	INSTALLATION		SHEET	
		SOUTHWEST	LHAAP		1 OF 1 SHEETS	
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6938032.10 3316534.70			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500			
4. HOLE NO. (As shown on drawing title and file number) LHS-MW70			13. OVERBURDEN SAMPLES		DISTURBED 9 UNDISTURBED 0	
5. NAME OF DRILLER RAY VOIS			14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER NOT DETERMINED			
7. THICKNESS OF OVERBURDEN 22.0			16. DATE HOLE		STARTED 09/00/1994 COMPLETED 09/00/1994	
8. DEPTH DRILLED INTO ROCK 0.0			17. ELEVATION TOP OF HOLE 180.5			
9. TOTAL DEPTH OF HOLE 22.0			18. TOTAL CORE RECOVERY FOR BORING 0.0 %			
R. PETERSON						
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
178.5			LEAN CLAY (CL) (0.0 - 2.0) WITH SAND, YELLOWISH BROWN, DAMP, FRIABLE.		J-1	TYPE AUGER ZONE 0.0- 22.0
175.0	3		LEAN CLAY (CL) (2.0 - 5.5) SANDY, YELLOWISH BROWN, DAMP, FRIABLE.		J-2	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 5.5 J-3 5.5- 7.0 J-4 7.0- 9.0 J-5 9.0- 13.0 J-6 13.0- 17.3 J-7 17.3- 18.8 J-8 18.8- 20.3 J-9 20.3- 22.0
173.5	6		LEAN CLAY (CL) (5.5 - 7.0) WITH SAND, GRAY AND YELLOWISH BROWN, DAMP, FRIABLE.		J-3	
171.5	9		SILT (ML) (7.0 - 9.0) SILTY CLAY WITH SAND, DARK BROWN, MOIST.		J-4	
167.5	12		LEAN CLAY (CL) (9.0 - 13.0) WITH SAND, YELLOWISH BROWN WITH GRAY AND RUST, MOIST, SILTY, SOME ORGANICS.		J-5	
163.2	15		CLAY SAND (SC) (13.0 - 17.3) YELLOWISH BROWN AND GRAY, MOIST, SILTY.		J-6	
161.7	18		FAT CLAY (CH) (17.3 - 18.8) GRAY WITH YELLOWISH BROWN, DAMP.		J-7	
160.2	21		LEAN CLAY (CL) (18.8 - 20.3) SANDY, YELLOWISH BROWN WITH RUST AND GRAY, WET, SOME CLAY CLUMPS.		J-8	
158.5	24		FAT CLAY (CH) (20.3 - 22.0) LIGHT GRAY, MOIST, SMALL AMOUNT OF SILT.		J-9	
	27					
	30					

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW70

WELL NO. LHS-MW70

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

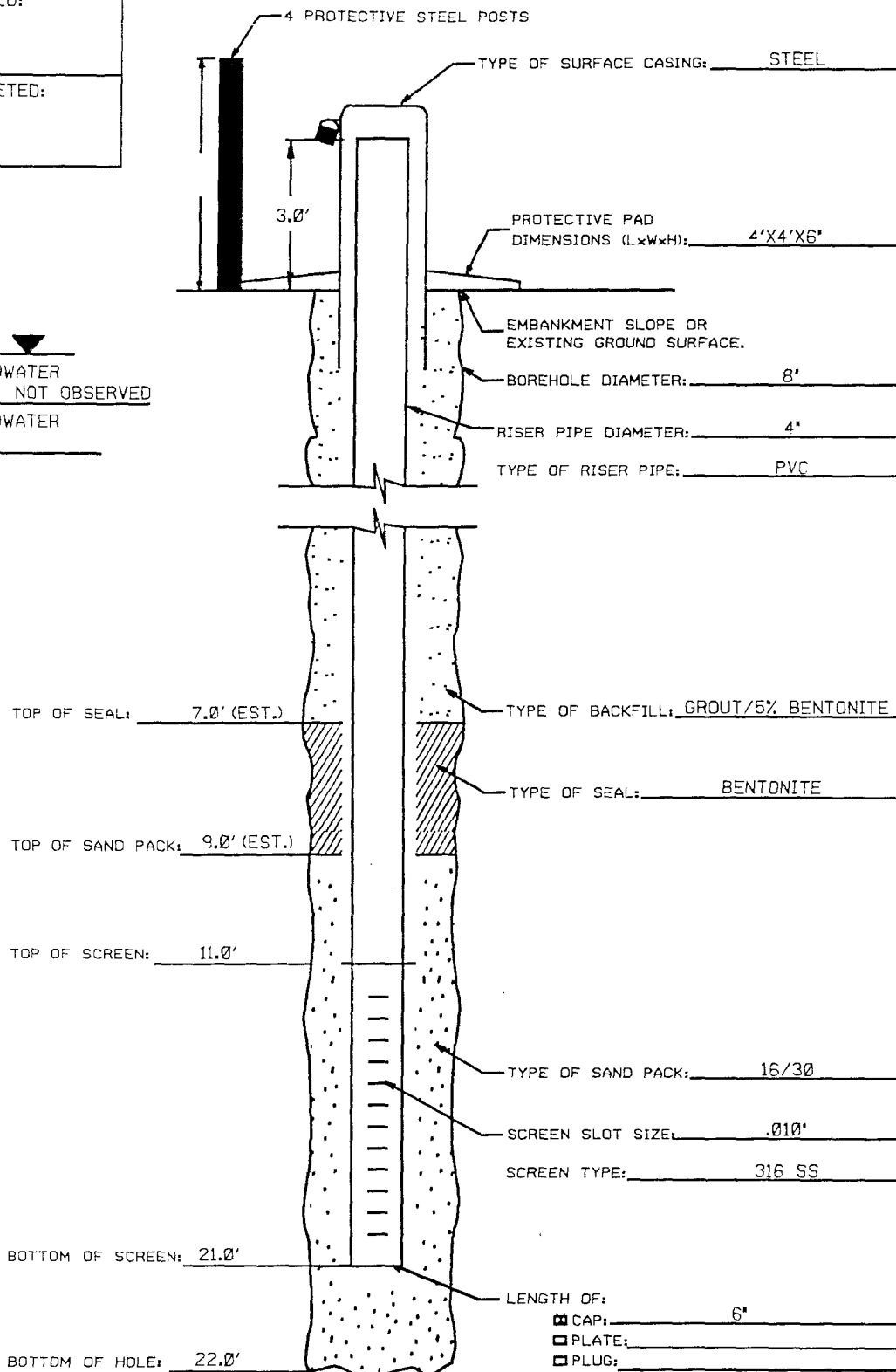
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE:



INSPECTOR:

RICHARD PETERSON

HOLE NO. LHS-MW71

DRILLING LOG		DIVISION	INSTALLATION	SHEET		
		SOUTHWEST	LHAAP	1 OF 1 SHEETS		
1. PROJECT LHAAP-WASTE SUMPS			10. SIZE AND TYPE OF BIT 8" AUGER			
2. LOCATION (Coordinates or Station) 6958209.80 3316838.80			11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL			
3. DRILLING AGENCY TULSA DISTRICT COE			12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500			
4. HOLE NO. (As shown on drawing title and the number) LHS-MW71			13. OVERBURDEN SAMPLES		DISTURBED 9 UNDISTURBED 0	
5. NAME OF DRILLER RAY VOILS			14. TOTAL NUMBER CORE BOXES 0			
6. DIRECTION OF HOLE <input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER NOT DETERMINED			
7. THICKNESS OF OVERBURDEN 17.5			16. DATE HOLE STARTED 09/00/1994 COMPLETED 09/00/1994		17. ELEVATION TOP OF HOLE 180.9	
8. DEPTH DRILLED INTO ROCK 0.0			18. TOTAL CORE RECOVERY FOR BORING 0.0 %			
9. TOTAL DEPTH OF HOLE 17.5			R. PETERSON			
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
178.9	2		LEAN CLAY (CL) (0.0 - 2.0) STRONG BROWN, DAMP.		J-1	TYPE ZONE AUGER 0.0- 17.5
175.9	4		LEAN CLAY (CL) (2.0 - 5.0) YELLOWISH RED, MOIST, SOME GRASS.		J-2	SAMPLE DEPTH J-1 0.0- 2.0 J-2 2.0- 5.0 J-3 5.0- 6.0 J-4 6.0- 8.0 J-5 8.0- 13.5 J-6 13.5- 14.3 J-7 14.3- 14.7 J-8 14.7- 15.7 J-9 15.7- 17.5
174.9	6		SILT (ML) (5.0 - 6.0) SILTY CLAY WITH SAND, OLIVE BROWN, DAMP.		J-3	
172.9	8		LEAN CLAY (CL) (6.0 - 8.0) DARK YELLOWISH BROWN AND BROWN, MOIST.		J-4	
167.4	10		FAT CLAY (CH) (8.0 - 13.5) LIGHT GRAY AND YELLOWISH BROWN WITH RUST, MOIST.		J-5	
166.2	14		LEAN CLAY (CL) (13.5 - 14.7) WITH SAND, YELLOWISH BROWN AND GRAY TO BROWN AND LIGHT GRAY, MOIST TO VERY MOIST.		J-6	
165.2	16		SILT SAND (SM) (14.7 - 15.7) BROWN AND YELLOWISH BROWN, FREE WATER.		J-7	
163.4	18		FAT CLAY (CH) (15.7 - 17.5) YELLOWISH BROWN AND GRAY, MOIST.		J-8	
	20				J-9	

PROJECT
LHAAP-WASTE SUMPSHOLE NO.
LHS-MW71

WELL NO. LHS-MW71

MONITORING WELL SHEET

PROJECT & INSTALLATION:


LONGHORN ARMY AMMUNITION PLANT - SUMPS

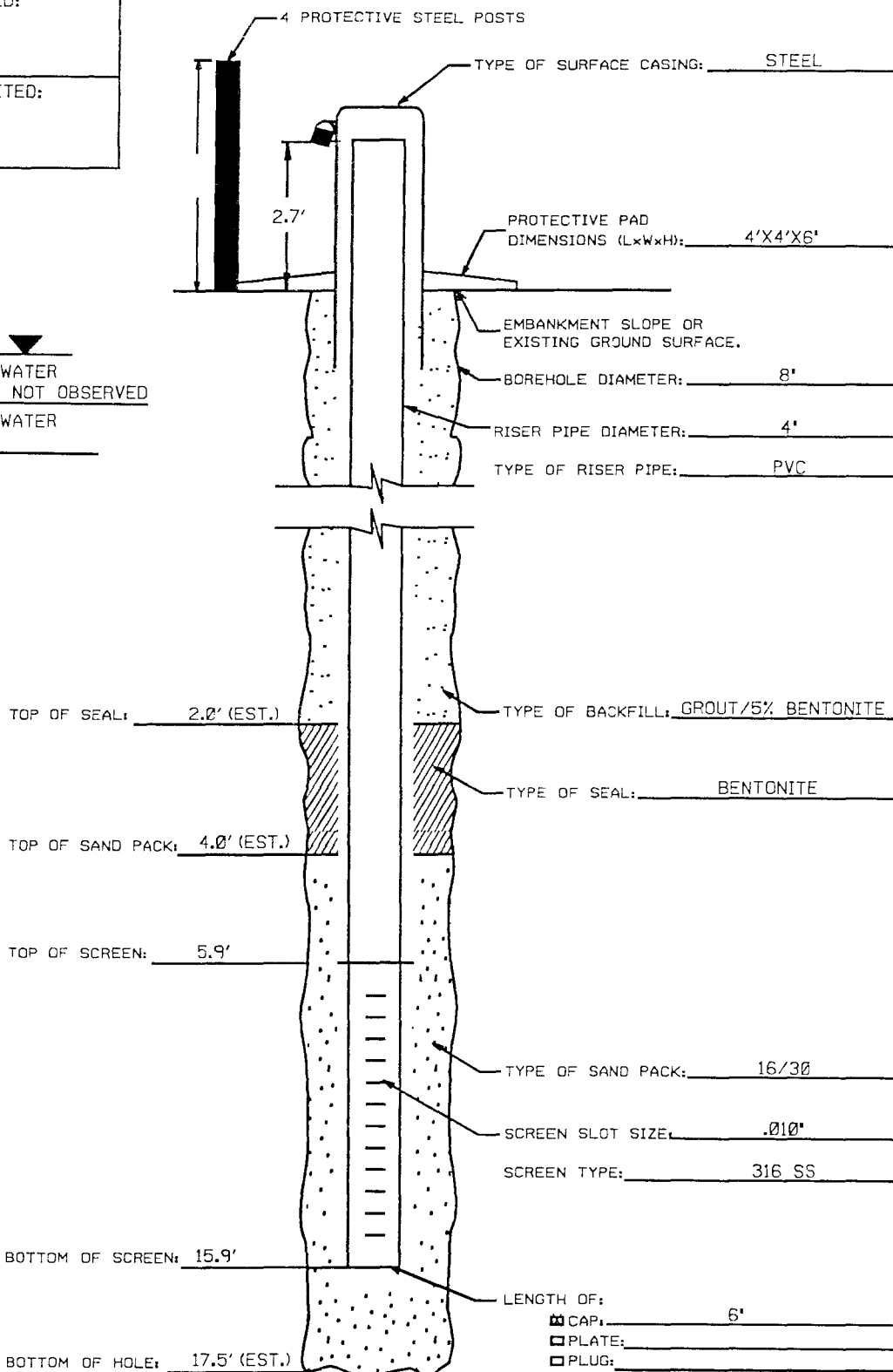
DATE STARTED:

9-1994

DATE COMPLETED:

9-1994


 GROUNDWATER
 DEPTH: NOT OBSERVED
 GROUNDWATER
 DATE: _____



INSPECTOR:

RICHARD PETERSON

	VISUAL U/S	BLOW COUNT*	MATERIAL CLASSIFICATION	% FINES	AQUIFER PERMEA- BILITY
0	SP-SM	9/7 10/5 6/8	Slightly silty sand Yellowish red	5-10	
	CL		Sandy clay 20% fine sand Gray and red		
5	SP-SM	3	Silty sand		
	CL	4/5 5/6 /10	Sandy clay 20% fine sand Gray and red		
10	CL	3/3 4/5 6/7	Slightly sandy clay 5% fine sand Light olive gray		
	CL		Sandy clay 15% fine sand Lt. olive grey w/reddish yellow	29.0	1.1 x 10 ⁻³ ft/min
	SP-SM	2/11 6/8	Silty sand-light grey	34.4	
	SM	/7	Silty sand Light grey mottled w/reddish yellow	24.6	
20	SM	4/5 /7	Silty sand Yellowish brown	28.1	
25					
30					
35					

*BLOWS PER 6 INCH USING
18, 24, or 36 SPLITSPOON

VERTICAL SCALE 1" = 5.0'

WELL 107 DATE DRILLED 5/16/82
STUDY AREA Static Test Area

ELEVATION TOP OF STEEL CASING = 178.11 ft
ELEVATION TOP OF PVC RISER = 177.56 ft
ELEVATION OF GROUND SURFACE = 174.97 ft

SOURCE: ENVIRONMENTAL PROTECTION SYSTEMS, INC. - 1983

CONTAMINATION SURVEY
LONGHORN ARMY AMMUNITION PLANT
MARSHALL, TEXAS

U. S. ARMY TOXIC AND HAZARDOUS
MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND