

**FINAL  
REMEDIAL PROCESS OPTIMIZATION REPORT  
FOR  
SITE LF014 CONTAMINANT PLUME  
ZONE 1  
KELLY AIR FORCE BASE, TEXAS**

**Prepared for:**

**CONSULTANT OPERATIONS DIVISION  
BROOKS AIR FORCE BASE, TEXAS**

**and**

**SA-ALC/ EMRR  
KELLY AIR FORCE BASE, TEXAS**

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## LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE/ERT	Air Force Center for Environmental Excellence/Technology Transfer Division
AMC	Air Mobility Command
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ASCE	American Society of Civil Engineers
bgs	below ground surface
BRA	baseline risk assessment
CAH	chlorinated aliphatic hydrocarbon
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMS	corrective measures study
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
2-D	two dimensional
3-D	three dimensional
DCE	dichloroethene
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
EM	electromagnetic
EPCF	Environmental Process Control Facility
ES	Engineering-Science, Inc.
ETI	EnviroMetals Technologies, Inc.
FFS	focused feasibility study
FS	feasibility study
ft/day	feet per day
ft/ft	foot per foot
gpm	gallons per minute
GWP	groundwater protection
HASP	health and safety plan
HNUS	Halliburton NUS Corporation
IRP	Installation Restoration Program
LTM	long-term monitoring
µg/L	micrograms per liter
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation

MSC	medium-specific concentration
O&M	operations and maintenance
OM&M	operation, maintenance, and monitoring
OPS	operating properly and successfully
ORP	oxidation/reduction potential
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
Parsons ES	Parsons Engineering Science, Inc.
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCL	protective concentration limit
POC	point of compliance
POL	petroleum, oils, and lubricants
PQL	practical quantitation limit
PRB	permeable reaction barrier
PRG	preliminary remediation goal
PVC	polyvinyl chloride
Radian	Radian Corporation
RAO	remedial action objective
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
redox	reduction/oxidation
RG	remediation goal
RI	remedial Investigation
RNA	remediation by natural attenuation
ROD	record of decision
RPO	remedial process optimization
RRR	Risk-Reduction Rules
RRS	risk-reduction standard
RW	recovery well
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SMCL	secondary maximum contaminant level
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TAC	Texas Administrative Code
TCE	trichloroethene
TNRCC	Texas Natural Resource Conservation Commission
TPH	total petroleum hydrocarbons
TRRP	Texas Risk-Reduction Program
TSS	total suspended solids
TW	temporary well
TWQS	Texas water quality standards
US	United States

USAF	US Air Force
USEPA	US Environmental Protection Agency
UVOX	ultra-violet light oxidation
VC	vinyl chloride
VOC	volatile organic compound
WWTP	wastewater treatment plant

## EXECUTIVE SUMMARY

Parsons Engineering Science, Inc. (Parsons ES) prepared a draft remedial process optimization (RPO) handbook for the Air Force Center for Environmental Excellence, Technology Transfer Division (AFCEE/ERT). The handbook will be used by AFCEE to review the performance of existing remediation systems, implement performance enhancements on existing systems, perform 5-year Record-of-Decision (ROD) reviews, and prepare documentation for operating-properly-and-successfully certification for sites at Air Force facilities. Parsons ES is field-testing the approach described in the draft handbook at multiple Air Force sites, including groundwater associated with Site LF014 at Kelly Air Force Base (AFB), Texas. Lessons learned from the RPO field tests will be incorporated into the final RPO handbook. The Air Force goals for the RPO program are to: 1) assess the effectiveness of particular remedial actions; 2) enhance the efficiency of the remedial actions examined; and 3) when possible, identify annual operating, maintenance, and monitoring (OM&M) cost savings in excess of 20 percent for each system evaluated.

At Site LF014, which is a landfill, the Air Force is operating an interim groundwater extraction system that is intended to prevent discharge of a dissolved contaminant plume to the adjacent Leon Creek. The primary contaminants of concern (COCs) in groundwater are chlorinated aliphatic hydrocarbons (i.e., trichloroethene [TCE], 1,2-dichloroethene [1,2-DCE], and vinyl chloride [VC]); however, metals also are a potential concern. The combined flow from the 14-well extraction system is pumped to a ultra-violet-light (UVOX) plant for treatment and eventual discharge to Leon Creek. A previous investigation suggested that the current extraction well system is providing little containment of the groundwater plume, and replacement of the wells with a groundwater extraction trench was recommended.

The objectives of the RPO evaluation for Site LF014 include:

- Reviewing the remedial action objectives (RAOs) and remedial goals (RGs) developed for the site in light of the current regulatory environment;
- Refining the identification of significant contaminant source areas at Site LF014;
- Assessing the degree to which natural attenuation is transforming dissolved contaminant concentrations to less toxic or nontoxic substances;
- Assessing the benefits of installing an air sparging curtain or permeable reactive barrier (e.g., iron filings wall) versus a groundwater extraction trench; and
- Reviewing the current long-term monitoring (LTM) plan for the site and recommending modifications as appropriate.

Supplemental site characterization activities were performed in January 2000 to achieve the RPO evaluation objectives. These activities included installing temporary monitoring wells and piezometers, collecting groundwater samples for volatile organic compound and natural attenuation indicator parameter analysis, and measuring water levels.

## REVIEW OF CONCEPTUAL SITE MODEL

The conceptual site model developed for the site during previous studies was reviewed on the basis of both historical and newly-collected characterization data. Based on this review, the following conclusions were derived:

- The Navarro Clay surface underlying the surficial aquifer has been eroded into a series of mounds (topographic highs) and depressions to a greater degree than previously known. Therefore, if a cutoff trench is constructed parallel to the creek in the future, care should be taken to ensure that it is consistently keyed into the Navarro Clay to prevent underflow of dissolved contaminants.
- The relatively elevated TCE concentrations in the northwest portion of the site are indicative of a continuing source of TCE in the landfill. Concentrations of the reductive dehalogenation daughter product VC detected in this area were relatively low, suggesting incomplete microbial transformation of TCE and 1,2-DCE. In contrast, lower TCE concentrations detected further to the southeast suggest a decreasing source. VC concentrations in this area were higher, perhaps indicating an older plume with more complete microbial transformation of TCE and 1,2-DCE.
- Preliminary groundwater-to-surface-water discharge calculations suggest that contaminants discharging to Leon Creek are substantially diluted. State regulations allow the effects of dilution and mixing to be accounted for when assessing the impact of contaminant discharge to surface water; therefore, a more accurate assessment of the groundwater discharge rate should be made to facilitate remedial decision-making.
- The northeast and north-central magnetic anomalies identified during the remedial investigation of the site appear to be associated with elevated contaminant concentrations in groundwater, and therefore may represent significant source areas. Other, lower-magnitude magnetic anomalies also may represent significant source areas. At a minimum, consideration should be given to performing exploratory trenching in the northeast and north-central magnetic anomaly areas. A decision to more completely excavate these areas should be made following exploratory trenching.
- Chemical and geochemical data strongly indicate that anaerobic, reducing conditions are present within the landfill that are conducive to reductive dehalogenation of CAHs. However, the continued presence of TCE and 1,2-DCE in many portions of the landfill indicates incomplete microbial transformation.
- Groundwater extraction rates for individual extraction wells confirm that the hydraulic characteristics of the surficial aquifer are spatially very variable, and suggest that non-uniform (preferential) migration of CAHs is occurring through more permeable zones. The discontinuous nature of the permeable gravel zone makes plume capture with vertical wells impractical and ineffective.

## **EVALUATION OF REMEDIAL GOALS AND COCS**

Current Installation Restoration Program (IRP) documents for Zone 1 groundwater have relied on regulatory requirements specified in the 1993 Risk-Reduction Rule (RRR) promulgated by the Texas Natural Resource Conservation Commission (TNRCC). The Base could choose to continue remediation of Site LF014 under this rule or switch to the Texas Risk-Reduction Program (TRRP) promulgated in 1999. The TRRP is applicable beginning May 1, 1999 unless the Base informs the state that they would prefer to remediate/close the site under the RRR.

Based on information presented in Section 4 of this report, the long-term benefits of the TRRP appear to outweigh the temporary inconvenience and cost of switching rules for the following reasons:

- The baseline risk assessment (BRA) completed for Site LF014 may require revision under the RRR, whereas a BRA is not required under the TRRP.
- If it is assumed that Site LF014 groundwater could potentially be used as drinking water, RRR cleanup levels need to be achieved throughout the plume. In contrast, the TRRP provides the option to control and manage the COCs without active remediation through the use of a plume-management zone.
- The TRRP provides clear guidance on the use of a dilution factor when assessing groundwater discharge to surface water.
- Target risk levels specified in the TRRP are less conservative than the risk levels specified under the RRR.

The Base has notified the TNRCC that it intends to proceed under the RRRs. However, this does not preclude the Base from changing to the TRRP at a later date. If the Base chooses to remain under the RRRs, then regulatory acceptance of a future land use other than residential should be pursued. In addition, a site-to-background comparison should be performed for metals, and statistical comparisons between site concentrations and preliminary cleanup levels should be conducted per USEPA and TNRCC guidance.

## **EVALUATION OF REMEDIAL SYSTEM**

The Base is currently evaluating alternatives to the existing extraction well system at Site LF014 to provide improved containment of groundwater. Other remedial actions under consideration include installation of a soil vapor extraction (SVE) system in the northwestern portion of the site to reduce the contaminant source, and regrading/revegetation of the site to minimize precipitation infiltration and resultant leachate generation.

Intentional releases of contaminants exceeding applicable surface water standards into waters of the State (including Leon Creek) is a violation of Chapter 26 of the Texas Water Code. Therefore, a remedial alternative consisting solely of monitored natural attenuation (MNA) does not appear to be an option for Site LF014 unless it can be demonstrated to the satisfaction of TNRCC that dilution/mixing of contaminants

discharging to the creek would prevent exceedance of state surface water and sediment standards.

Potentially promising technologies were identified and evaluated for their potential application to interception of the contaminant plume near the edge of Leon Creek. Technologies evaluated include an actively pumped extraction trench, a permeable reactive barrier (e.g., zero-valent iron wall), and an air sparging curtain.

Based on the evaluation of remedial alternatives performed as part of this RPO assessment, more detailed evaluation of the thickness and cost of a permeable reactive barrier is recommended prior to making a final decision regarding an alternative groundwater remedy. The cost of a permeable reactive barrier could potentially be reduced under any one of the following conditions:

- if a more detailed assessment of groundwater flow velocities within the gravel zone along the proposed trench corridor indicates that assumed velocities are overestimated, and thus the trench could be narrower than was assumed for costing purposes;
- if maximum dissolved contaminant concentrations are not used for design purposes; and/or
- if treatment of groundwater to drinking water levels is not required due to the effects of dilution and volatilization in Leon Creek.

However, this recommendation is conditional on the flexibility of the remedial schedule, because installation of a permeable reactive barrier would require revision of the feasibility study (FS) and Record of Decision (ROD), and additional interactions with the regulators.

It should be noted that a much smaller groundwater extraction/treatment wall (extraction trench, permeable reactive barrier, or air sparging curtain) may be adequate because dilution calculations and actual stream sampling may show that surface water criteria are exceeded by a relatively small portion of the landfill leachate. The source of VOC contamination in the southeastern portion of the landfill appears to be decreasing, and concentrations of TCE are relatively low. The ongoing benefits of natural attenuation should be considered when determining the need for groundwater extraction/treatment in the southern portion of the landfill.

It should also be noted that the recommendation to install a groundwater extraction trench is based on the assumption that the two other recovery well systems in Zone 1 continue to operate. If these systems cease operation and the only flow to the groundwater treatment plant is from Site LF014, then the attractiveness of a non-pumping remedial system (e.g., permeable reactive barrier wall) would be enhanced.

## **EVALUATION OF MONITORING PLAN**

Currently, the groundwater monitoring plan for Site LF014 consists of annual sampling of 12 monitoring wells, including point-of-compliance (POC) wells, corrective action observation wells, and a background well. Samples from these wells are analyzed

for volatile and semivolatile organic compounds, total metals, pesticides/PCBs, and cyanide.

A screening-level series of geostatistical calculations indicated that the regions of greatest uncertainty occur within the rectangle formed by wells LF014MW009, LF014MW012, LF014MW004, and LF014MW026, and between LF014MW027 and LF014MW004. Based on a qualitative analysis of the monitoring plan, continued monitoring of 8 of the 12 above-mentioned wells is recommended. The following revisions to the monitoring plan also are recommended:

- Replacement of two of the remaining four wells (LF014MW028 and LF014MW006) with other existing wells;
- Replacement of LF014MW003 with a new well in a different location;
- Deletion of one well (LF014MW004) from the monitoring program;
- Addition of two new wells (LF014MW075 and LF014MW078) for at least one sampling event; and
- Analysis of groundwater samples for dissolved metals and for both hexavalent and trivalent chromium.

Analysis for pesticides, PCBs, and cyanide should be reduced or eliminated based on the lack of detections of these compounds in site groundwater.

## **SUMMARY OF RPO OPPORTUNITIES**

RPO opportunities identified during this assessment are summarized in Table ES.1.

**TABLE ES.1  
SUMMARY OF RPO OPPORTUNITIES  
SITE LF014 CONTAMINANT PLUME  
REMEDIAL PROCESS OPTIMIZATION  
KELLY AFB, TEXAS**

Opportunity	Capital Cost Savings	Annual Cost Savings	Cost Savings Over 30-Year Period <sup>a/</sup>	Reduction in Time to Meet Cleanup Goals	Return on Investment Over 30-Year Period <sup>b/</sup>	Difficulty of Implementation	Cost To Implement
Reduce O&M costs by installing extraction trench (ET) or permeable reactive barrier (PRB)	NA <sup>c/</sup>	\$20,000 (ET) to \$90,000 (PRB)	\$600,000 (ET) to \$2,700,000 (PRB)	None	82% (PRB) to 140% (ET)	<b>Low (extraction trench) to Moderate (PRB)</b> —PRB would require revision of feasibility study and record of decision.	\$430,000 (ET) to \$3,300,000 (PRB) <sup>d/</sup>
Eliminate need for plume cutoff based on dilution calculations	\$430,000 (ET) to \$3,300,000 (PRB) <sup>d/</sup>	\$10,000 (PRB) to \$80,000 (ET)	\$300,000 (PRB) to \$2,400,000 (ET)	None	5,660% (ET) to 7,200% (PRB)	<b>High</b> —requires refinement of COC list, assessment of dilution effects, and regulatory approval.	\$50,000 <sup>e/</sup>
Reduce thickness of PRB by one-half based on refinement of groundwater velocity calculations	\$1,300,000	NA	NA	None	6,500%	<b>Low</b> – requires performance of additional aquifer (slug) tests and numerical modeling	\$20,000
Shorten extraction trench or PRB length based on dilution calculations <sup>f/</sup>	\$75,000 <sup>h/</sup> (ET) to \$700,000 (PRB)	\$0 (ET) to \$1,500 (PRB)	\$0 (ET) to \$45,000 (PRB)	None	150% (ET) to 1,490% (PRB)	<b>Moderate</b> —requires refinement of COC list, assessment of dilution effects, and regulatory approval	\$50,000 <sup>e/</sup>
Delete PCBs, pesticides, and cyanide from analytical program	NA	\$4,000	\$120,000	None	2,400%	<b>Moderate</b> – requires regulatory approval	\$5,000
Excavate selected magnetic anomaly areas	NA	TBD <sup>g/</sup>	TBD	TBD	TBD	<b>Moderate</b> – requires excavation and disposal of potentially hazardous materials	TBD

**TABLE ES.1 (Continued)**  
**SUMMARY OF RPO OPPORTUNITIES**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Opportunity	Capital Cost Savings	Annual Cost Savings	Cost Savings Over 30-Year Period <sup>a/</sup>	Reduction in Time to Meet Cleanup Goals	Return on Investment Over 30-Year Period <sup>b/</sup>	Difficulty of Implementation	Cost To Implement
Derive alternate cleanup levels for groundwater under the 1993 RRRs <sup>h/</sup>	TBD	TBD	>\$1 million <sup>i/</sup>	TBD	TBD	<b>Moderate</b> -requires regulatory approval.	\$10,000

<sup>a/</sup> Costs given in constant 2000 dollars.

<sup>b/</sup> Return on Investment = (capital + annual cost savings over 30-year period)/(cost to implement).

<sup>c/</sup> NA = not applicable.

<sup>d/</sup> Estimated cost to install 800-foot-long groundwater extraction trench or permeable reactive barrier.

<sup>e/</sup> Assumed cost to achieve trench reduction or elimination includes performance of six aquifer slug tests (\$3,000), analysis of 32 groundwater samples for dissolved metals (\$6,000) and both trivalent and hexavalent chromium (\$1,000), performance of a site-to-background comparison and statistical comparisons between site concentrations and preliminary cleanup levels (\$15,000), performance of a dilution analysis (\$10,000), and numerical modeling to estimate the groundwater discharge rate to Leon Creek (\$15,000). The modeling cost assumes recalibration of the existing flow model constructed by SAIC (1998).

<sup>f/</sup> Assuming 200-foot reduction in trench length.

<sup>g/</sup> TBD = to be determined.

<sup>h/</sup> RRRs = Risk Reduction Rules (Industrial Solid Waste and Municipal Hazardous Waste, Chapter 335, Subchapter S of the TAC).

<sup>i/</sup> Cost savings would only be realized if engineered cleanup of the groundwater plume and associated source area is required under the 1993 RRRs.

# SECTION 1

## INTRODUCTION

This document was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the United States (US) Air Force Center for Environmental Excellence/Consultant Operations Division (AFCEE/ERC), as part of a delivery order under US Air Force (USAF) Air Mobility Command (AMC) contract F11623-94-D0024, RL 72. The scope of this delivery order includes preparing a guidance document for remedial process optimization (RPO), and evaluating the approach described in the RPO guidance document at selected Air Force demonstration sites. This report outlines the results of the RPO field evaluation for Site LF014 (Installation Restoration Program [IRP] Site LF014), Zone 1 at Kelly Air Force Base (AFB), Texas. The Air Force goals for the RPO program are to:

- Assess the effectiveness of the remedial action;
- Augment the efficiency of the remedial action; and
- When possible, identify annual operating, maintenance, and monitoring (OM&M) cost savings in excess of 20 percent for each system evaluated.

As indicated above, the primary objective at most of the Air Force RPO demonstration sites is to evaluate the performance of the existing remedial system using the guidance presented in the *Remedial Process Optimization Handbook* (Parsons ES, 1999a). The handbook will be used by AFCEE to review the performance of existing remediation systems, implement performance enhancements on existing systems, perform 5-year record-of-decision (ROD) reviews, and prepare documentation for "operating properly and successfully" (OPS) certification.

The appropriateness, adequacy, and efficiency of the existing groundwater extraction system at Site LF014 was previously evaluated by Science Applications International Corporation (SAIC, 1998). Therefore, the primary objectives of the Site LF014 RPO evaluation include:

- Reviewing the remedial action objectives (RAOs) and remedial goals (RGs) developed for the site in light of the current regulatory environment;
- Refining the identification of significant contaminant source areas at Site LF014;
- Assessing the benefits of installing an air sparging curtain or permeable reactive barrier (e.g., iron filings wall) versus SAIC's recommendation for a groundwater extraction trench;

- Assessing the degree to which natural attenuation is transforming dissolved contaminant concentrations to less toxic or nontoxic substances; and
- Reviewing the current long-term monitoring (LTM) plan for the site and recommending modifications as appropriate.

To the extent feasible, these objectives have been accomplished using the guidance presented in the above-referenced RPO handbook. This effort required the performance of the following tasks:

- Reviewing data to evaluate previously completed site characterization and treatability study activities;
- Preparing a site-specific work plan (Parsons ES, 1999b) and a site-specific addendum to the project health and safety plan (HASP) (Parsons ES, 1998);
- Collecting groundwater samples at closely spaced (approximately 25-foot) intervals along and near the existing line of extraction wells to refine the identification of significant contaminant source areas and identify preferential contaminant migration pathways;
- Analyzing selected groundwater samples for a suite of natural attenuation indicator parameters in order to evaluate the degree to which volatile organic compounds (VOCs) dissolved in groundwater are being biodegraded;
- Evaluating alternatives for engineered cutoff of the contaminant plume near Leon Creek;
- Reviewing the current regulatory environment under which remedial actions at the site are being performed, and assessing the appropriateness of applicable or relevant and appropriate requirements (ARARs), RAOs, and RGs identified for the site; and
- Reviewing the current LTM plan, including wells selected for sampling, the analytical program, and the sampling frequency, to determine if modifications would increase the effectiveness and/or reduce the cost of monitoring.

The results of the RPO evaluation conducted at Site LF014 are presented in this report.

## **1.1 DESCRIPTION OF THE RPO PROCESS**

RPO is a systematic approach for evaluating and improving the effectiveness and efficiency of site remediation so that maximum risk reduction is achieved for each dollar spent. Although RPO is associated with the optimization of remediation systems and *how* the cleanup will be completed, it also reviews *why* certain cleanup goals have been established, and updates those decisions based on new regulatory options. Just as the technical approach to remediation should be upgraded to take advantage of scientific advances, changes in regulatory framework such as risk-based cleanup goals and the growing acceptance of monitored natural attenuation (MNA) should be considered in the optimization process. An effective RPO program pursues a wide range of optimization opportunities.

## **1.2 REPORT ORGANIZATION**

This report is organized into eight sections, including this introduction, and three appendices. An overview of site conditions and previous investigations is provided in the remainder of Section 1. The January 2000 field sampling program performed by Parsons ES is described in Section 2, and a review of the conceptual site model is presented in Section 3. Section 4 provides an evaluation of the cleanup goals. Section 5 presents an evaluation of remedial alternatives. Section 6 presents an evaluation of the existing groundwater monitoring plan for the site and Section 7 presents recommendations for short- and long-term RPO opportunities. References are listed in Section 8. Appendix A provides details regarding the calculation of risk-based cleanup standards. Appendix B presents the cost evaluation for the remedial alternatives evaluation and site-specific information regarding permeable reactive barriers received from the vendor (EnviroMetal Technologies, Inc. [ETI]). Appendix C contains groundwater-to-surface water discharge calculations, and Appendix D contains the results of dilution modeling performed for the site. Appendix E contains pertinent and helpful regulatory guidance documents. Appendix F contains complete VOC results for samples collected in January 2000, and Appendix G is a figure showing magnetic anomalies previously detected at the site.

## **1.3 SITE DESCRIPTION AND OPERATIONAL HISTORY**

Kelly AFB is located in Bexar County, Texas, approximately 7 miles southwest of the center of San Antonio. The Base is bounded on the west by Lackland AFB and on the south by Military Highway and Leon Creek. The eastern and northern boundaries of Kelly AFB are the Missouri-Pacific Railroad yards and Highway 90, respectively. Zone 1 consists of 383 acres located in the southwestern portion of Kelly AFB (Figure 1.1). A large portion of Zone 1, including Site LF014, coincides with the present-day golf course, and the Air Force plans to continue using the land as a recreational facility. As shown on Figure 1.2, Site LF014 is located in the southeastern portion of Zone 1.

The LF014 landfill, which encompasses an area of approximately 14 acres, was operational between 1950 and 1958. However, aerial photographs indicate that the area was used as a landfill during the early 1940s as well. LF014 was used to dispose of hardfill; general refuse; waste petroleum, oils, and lubricants (POL); electroplating sludge drums; solvents; and pesticides. The site contains four former disposal areas, as shown on Figure 1.3. The two most northern areas contain cut-and-fill trenches, which were excavated to depths of 8 to 12 feet. The surficial expression of the landfill trenches consists of a series of parallel swales separated by gentle swells that are still visible at the site. Available information indicates that the trenches were 80 to 800 feet long and 15 to 18 feet wide. Nonhazardous soil-and-rubble fill was placed in the two southern disposal areas.

## **1.4 PREVIOUS INVESTIGATIONS**

Previous investigations performed at Site LF014 are summarized in the following subsections.

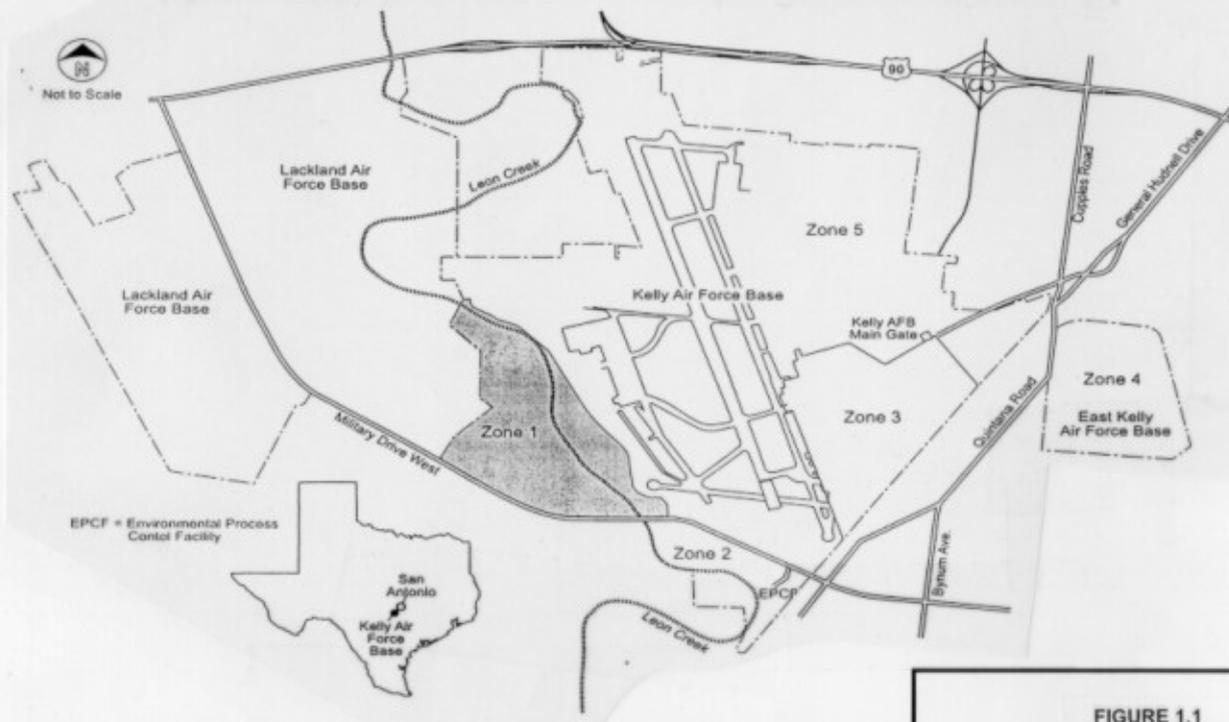


FIGURE 1.1  
 LOCATION OF KELLY AFB  
 AND ZONE 1

Site LF014 Contaminant Plume  
 Remedial Process Optimization  
 Kelly AFB, Texas

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FIGURE 1.2

LOCATION OF SITE LF014

Site LF014 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

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#### **1.4.1 Phase I Records Search**

A Phase I records search for Site LF014 was performed by Engineering-Science, Inc. (ES, 1982). The historical information presented in Section 2.1.1 was derived from this records search. Based on the results of this study, field sampling was recommended.

#### **1.4.2 Phase II Field Investigation**

Phase II field investigations were conducted by Radian Corporation (Radian, 1984 and 1988). Six monitoring wells were installed, and multiple groundwater sampling events were performed. Groundwater analytical results indicated the presence of chlorinated aliphatic hydrocarbons (CAHs) and monocyclic aromatics. In addition, inorganics were present above background levels or US Environmental Protection Agency (USEPA) maximum contaminant levels (MCLs).

#### **1.4.3 Remedial Investigation**

A remedial investigation (RI) of Zone 1 groundwater, including Site LF014, was performed by Halliburton NUS (HNUS, 1992a). The objective of the RI was to characterize the nature and extent of contamination in soil and groundwater, and to provide an assessment of the potential risks associated with the study sites. Empty, rusted, and partially intact drums were observed during the RI at the surface at the northeastern end of the central waste disposal trenches. Landfill trenches were not visible at the southern end of the site; however, concrete rubble was present at the surface.

Field investigations performed during the RI included geophysical (magnetic and electromagnetic [EM]) surveys; drilling and sampling of 33 soil borings; soil gas sampling; installation of nine temporary and four permanent monitoring wells; one pumping well and nine observation wells (for a pump test); and collection of groundwater samples for laboratory analysis. Results of laboratory analyses and the geophysical and soil gas surveys indicated three potential source areas, including linear landfill trenches and buried drums within the northern and central portions of the site. The RI report concluded that the most significant VOC contamination is sourced in the northeastern portion of the site.

#### **1.4.4 Focused Feasibility Study**

An FFS for selecting an appropriate interim remedial action for contaminated groundwater was finalized in 1992 (HNUS, 1992b). Based on the results of the FFS, interim remedial system construction at Site LF014 (14 groundwater extraction wells) began in 1993. Additional details regarding the interim remediation system are provided in Section 1.8.

#### **1.4.5 Feasibility Study for Groundwater**

As a result of the groundwater FS performed by HNUS (1996), Alternative OU1-14 was selected as the preferred remedial alternative for Operable Unit (OU) 1 groundwater following public review. OU1 includes Zone 1 sites LF014 and LF015. The Texas Natural Resource Conservation Commission (TNRCC) has concurred with the selection of this alternative. Alternative OU1-14 includes the following elements:

- Administrative controls;
- Installation of 10 monitoring wells;
- Operation and maintenance (O&M) of the 14 existing extraction wells;
- O&M of treatment systems (see Section 1.8);
- Discharge of treated groundwater to Leon Creek; and
- Reevaluation every 5 years.

#### **1.4.6 Corrective Measures Study for Soils**

Six remedial alternatives were evaluated for Site LF014 during the soils corrective measures study (CMS) performed by CH2M Hill (1999d). These alternatives ranged from no further action to source area excavation. A soil remedial alternative will be selected following TNRCC review of the draft final CMS report, which was submitted for review in April 1999. The CMS is scheduled to be completed in September 2000.

#### **1.4.7 Interim Groundwater Recovery System Evaluation**

SAIC (1998) evaluated the appropriateness, adequacy, and efficiency of the existing groundwater extraction system at Site LF014 described in Section 1.4.4. Other objectives of this evaluation included:

- Characterizing the shallow aquifer, including estimating aquifer parameters and evaluating of the conceptual hydrogeologic model of the site;
- Delineating the groundwater plume to ensure that major sources had not been overlooked and that excessive clean water is not being pumped from some areas; and
- Installing additional monitoring wells to properly evaluate the interim remedial system.

Investigations at Site LF014 included a well-by-well evaluation, including pumping tests, and a geophysical survey to attempt to locate gravel channels within the shallow aquifer. In addition, the numerical groundwater flow model used to design the Site LF014 extraction system (HNUS, 1992b) was updated based on new site characterization information to evaluate the efficiency and adequacy of the remedial system, and to make recommendations for improvement.

Significant findings of this evaluation for the Site LF014 pump-and-treat system included the following (SAIC, 1998):

- The contaminant source(s) at Site LF014 have not been, and may not be able to be, characterized due to the heterogeneous nature of the contamination (landfill materials). If sources are not characterized and aggressively remediated, the site groundwater RGs will not be attained.

- Trichloroethene (TCE) was detected at a concentration of 93,000 micrograms per liter ( $\mu\text{g/L}$ ) in groundwater from one monitoring well. This concentration is an order of magnitude higher than the maximum concentration detected during previous investigations.
- The pumping wells at Site LF014 generally are not efficient, and their radius of influence is limited.
- Wells screened in the most transmissive portion of the aquifer have no noticeable drawdown, indicating poor containment of the dissolved contaminant plume. Pumps in these wells are too small.
- Results from the revised groundwater model suggest that the current extraction system is providing little plume containment. This situation cannot be corrected simply by changing the pump size because a majority of the wells are not screened in materials with transmissivities high enough to create overlapping capture zones. Many of the wells are installed in clayey deposits, and are not pumping at their design flow rates.
- Some of the wells installed in 1993 have deteriorated (e.g., fine roots were found in one well, and abundant silt is present in another); the system is aging.
- Recharge from golf course irrigation, the golf course pond, and a storm drain outfall creates a significant amount of unnecessary leachate, making leachate control more difficult than it should be.
- Stratigraphic information indicates that a low-permeability clay zone is present adjacent to the creek in the southeastern portion of the site below the Leon Creek dam. This clay zone inhibits discharge of groundwater to Leon Creek. In areas where water-bearing materials are of low permeability, natural containment may be adequate because contaminant movement is retarded, and discharge to Leon Creek is limited.
- The system optimization in the area north of well LF014RW040 (Figure 1.3) should be a priority. Operation of most of the extraction wells south of LF014RW040 is not necessary due to low contaminant levels. Natural attenuation may effectively reduce the contaminant concentrations in this area to levels that would not pose a threat to human health or the environment.

Based on these findings, SAIC (1998) recommended the following actions:

- Replace the extraction well system at Site LF014 with an extraction trench, and install a cutoff (e.g., slurry) wall between the extraction trench and Leon Creek to minimize pumping of surface water; and
- As an interim measure (pending construction of the extraction trench and cutoff wall), increase the pump sizes in two of the LF014 extraction wells, and turn off or remove pumps from seven LF014 wells that are screened in low-permeability materials.

#### **1.4.8 Base-Wide Groundwater Flow Model**

A Base-wide groundwater flow model was constructed using the code MODFLOW-SURFACT (HydroGeoLogic, 1999). The model has a uniform 300-foot grid spacing to simulate groundwater flow at the regional scale. The primary benefit of the Base-wide model is to provide the conceptual and numerical framework from which to develop “zoom” models, which have smaller grid spacing and are designed to provide more detailed simulations for localized areas. The modeling approach at Kelly AFB is to update the Base-wide regional model when appropriate, and to construct zoom models for different contaminant plumes and different remediation systems on an as-needed basis.

### **1.5 SITE GEOLOGY AND HYDROGEOLOGY**

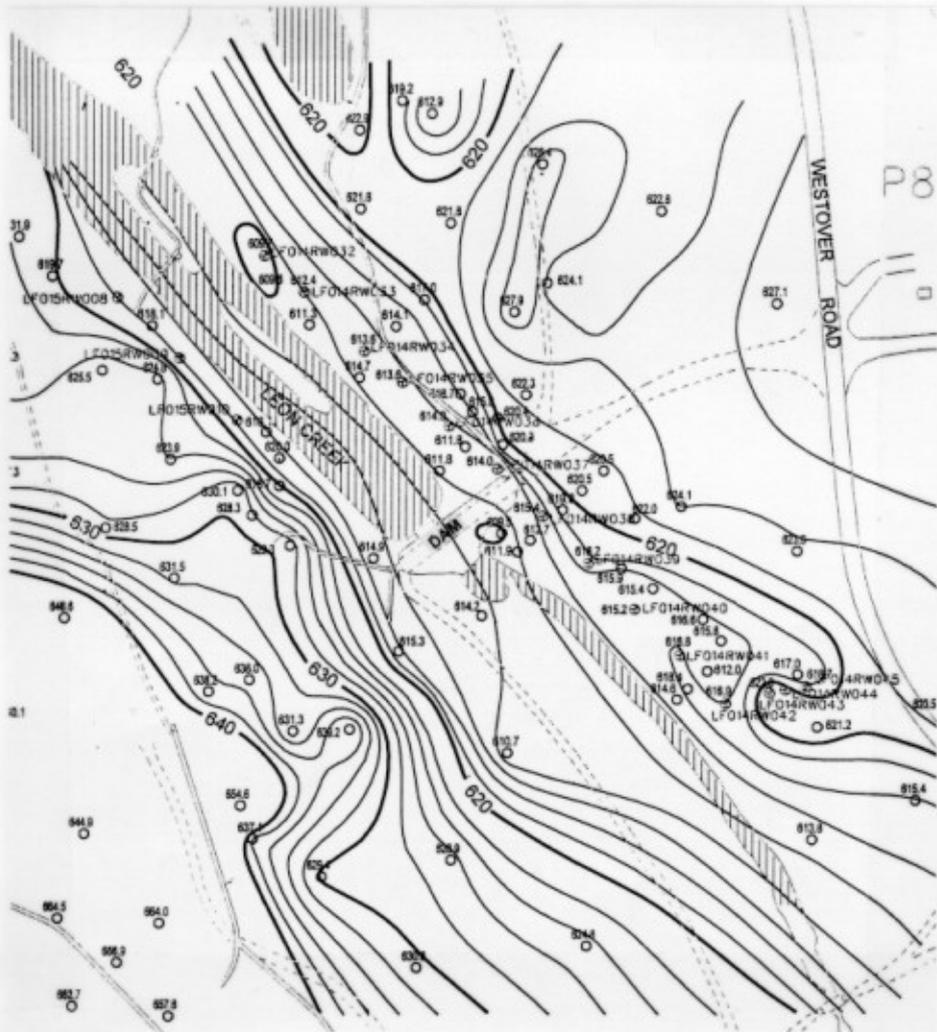
#### **1.5.1 Geology**

The subsurface at Site LF014 consists of approximately 5 to 24 feet of fill material and alluvial sediments overlying the Navarro Clay. The fill, which ranges from 1 to 22 feet in thickness, consists of silt and clay with trace to some sand, gravel, and caliche nodules. The undisturbed alluvium consists of clayey silt, sand, and clayey gravel to gravelly clay. The gravel thickness ranges from 1 to 12 feet, and does not appear to correspond with the topography of the Navarro Clay surface. The gravel does not form a continuous layer, but appears to be most laterally continuous near and parallel to Leon Creek. The surface of the Navarro Clay generally slopes toward Leon Creek, and there is a ridge beneath the road that connects the dam and Westover Road (Figure 1.4). A geologic cross-section through the line of groundwater extraction wells that is located approximately 60 feet northeast of Leon Creek is shown on Figure 1.5.

#### **1.5.2 Hydrogeology**

Depth to shallow groundwater at Site LF014 varies from approximately 1 to 20 feet below ground surface (bgs), and is generally less than 15 feet bgs. The saturated thickness above the Navarro Clay ranges from less than 1 to 15 feet and is generally greatest in areas where the surface of the Navarro Clay is topographically low (e.g., near Leon Creek). East of the southeast-flowing Leon Creek (beneath Site LF014), groundwater in the unconfined surficial aquifer flows in a generally southerly direction toward the creek (Figure 1.6), and discharges to the creek. A ridge of Navarro Clay creates a north/south-trending groundwater divide through the center of the site that intersects Leon Creek near the dam (Figures 1.4 and 1.5). The dam across Leon Creek has caused the water surface in the creek upstream from the dam to rise, which has resulted in a flattening of the hydraulic gradient between the LF014 waste disposal area and the creek along this upstream reach. It is likely that the flattening of the hydraulic gradient has limited the discharge of dissolved contaminants to the creek in this area, and recharge of the surficial aquifer from the creek may occur during periods of greater surface water flow.

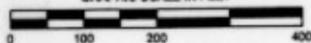
Slug test results indicate that the hydraulic conductivity of the fill material ranges from 0.6 to 150 feet per day (ft/day), with a geometric mean value of 4.1 ft/day. The hydraulic conductivity of the gravelly alluvium, based on slug test data, ranges from 0.03 to 1,500 ft/day, with a geometric mean value of 21 ft/day. Results from a pumping test performed in a landfill trench during the RI indicated an average hydraulic conductivity within the



**LEGEND**

- Navarro Clay Surface Elevation (ft above mean sea level)
- Navarro Clay Surface Elevation Contour
- ▨ Water Body

GRAPHIC SCALE IN FEET



**FIGURE 1.4**

**NAVARRO  
ELEVATION CONTOURS**

Site LF014 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

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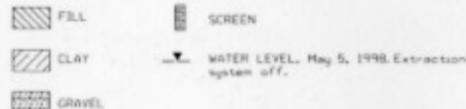
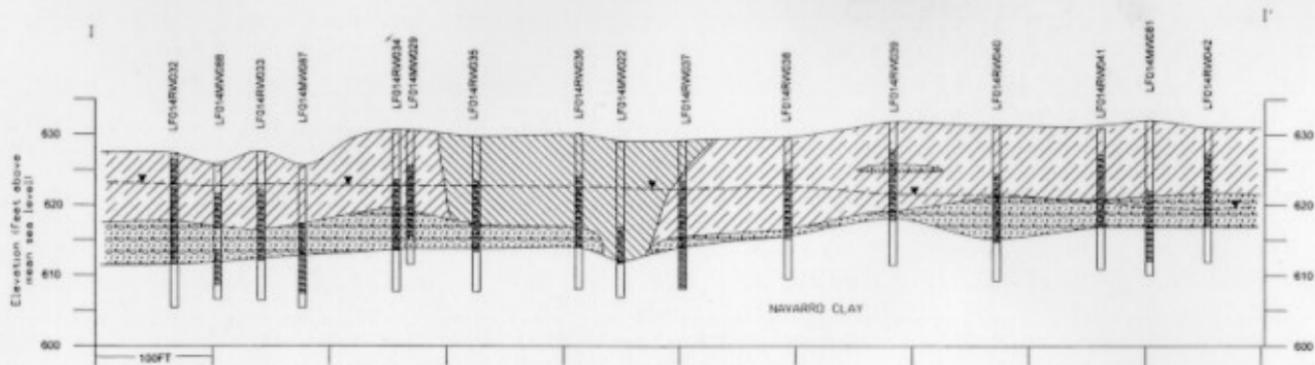
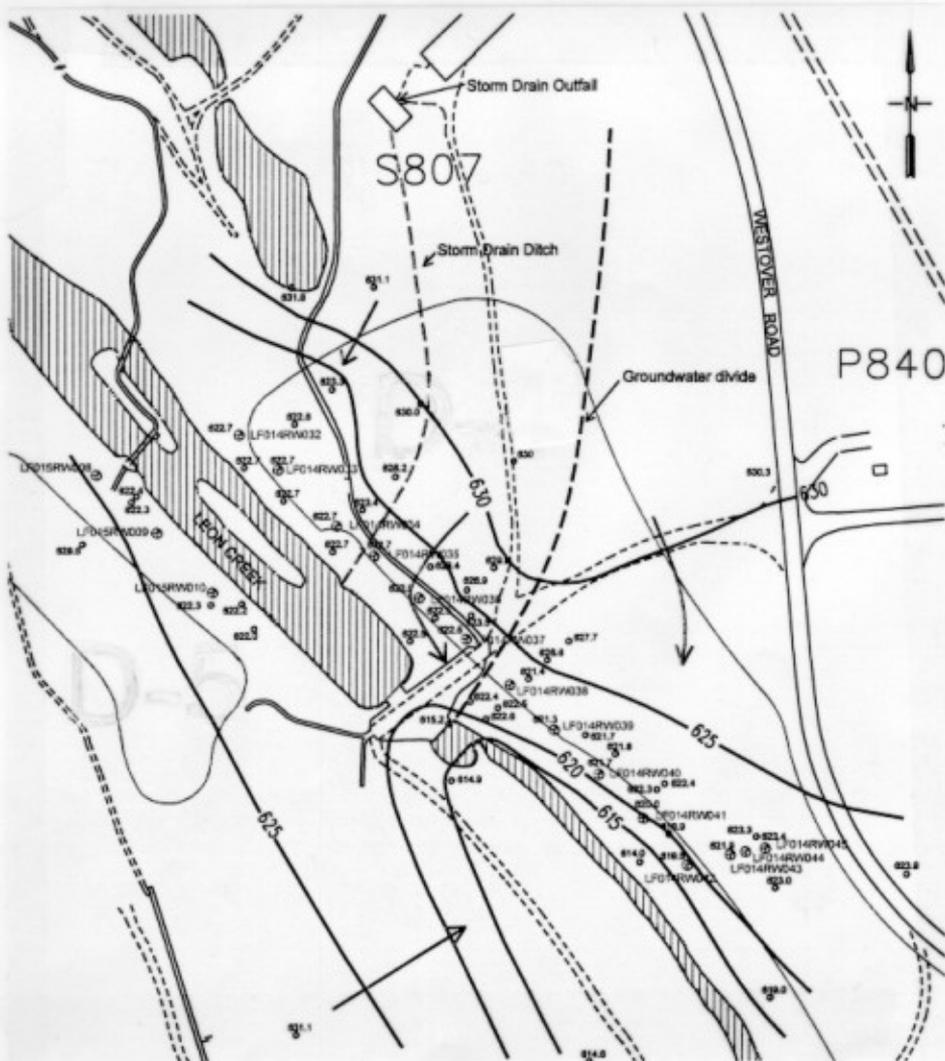


FIGURE 1.5

GEOLOGIC CROSS SECTION (I-I')

Site LFO14 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

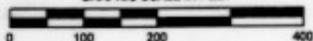
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**LEGEND**

- 631.1 Groundwater Elevation
- Groundwater Elevation Contour
- Groundwater Flow Path
- Groundwater Divide
- Surface Water Body
- Storm Drain Ditch

GRAPHIC SCALE IN FEET



**FIGURE 1.6**

**STATIC WATER LEVEL  
CONTOURS ON 5/5/98**

Site LF014 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

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trench of 68 ft/day (HNUS, 1992a). The average hydraulic conductivity outside the trench was calculated to be 190 ft/day. Hydraulic conductivities derived from a second pumping test performed by SAIC (1998) in the gravelly alluvium were 840 ft/day and 1,600 ft/day. The wide range of hydraulic conductivity values measured at the site indicates a high degree of subsurface heterogeneity.

## **1.6 NATURE AND EXTENT OF CONTAMINATION**

A description of the nature and extent of contamination at Site LF014 is provided in the following subsections. Soil information is excerpted from the soils CMS (CH2M Hill, 1999d), and groundwater and surface water/sediment information is derived from the groundwater RI (HNUS, 1992a) and the groundwater recovery system evaluation report (SAIC, 1998). Additional surface water and sediment data were obtained from semiannual compliance plan reports summarizing the results of Leon Creek sampling events performed in 1998 and 1999 (CH2M Hill, 1999a and 1999e). The RI report noted that organic and inorganic soil and groundwater contamination at Site LF014 appears to be associated primarily with three features: 1) a magnetic anomaly in the northeastern part of the site, 2) landfill trenches in the northern quadrant, and 3) a magnetic anomaly and exposed drums in the north-central portion of the site (HNUS, 1992a).

### **1.6.1 Soils**

The chemicals of concern (COCs) identified in Site LF014 soils include TCE, methylene chloride, lead, and selenium. Concentrations of each of these constituents exceeded site-specific RGs developed using site data and relevant receptor exposure scenarios. Lead exceeded the direct-contact criterion, while TCE, methylene chloride, and selenium exceeded the groundwater-protection (GWP) criteria. Methylene chloride and selenium were not detected in site groundwater at concentrations exceeding the USEPA MCLs. In contrast, concentrations of TCE and its degradation products dichloroethene (DCE) and vinyl chloride (VC) exceeded their respective MCLs in site groundwater.

### **1.6.2 Groundwater**

Organic groundwater contamination primarily consists of CAHs, although other organic compounds have been detected at much lower concentrations. The CAHs detected in groundwater at concentrations exceeding MCLs include TCE, VC, and 1,2-DCE. There does not appear to be significant vertical stratification of dissolved VOCs.

During the RI, 10 inorganics were detected in groundwater samples at concentrations exceeding background levels, including barium, calcium, cobalt, iron, magnesium, manganese, potassium, selenium, silver, and sodium. SAIC (1998) concluded that groundwater contaminants at Site LF014 are mainly organic compounds with occasional high levels of manganese. Because manganese is a common trace element of the natural groundwater, it was screened out of the COC list, and Site LF014 was designated to be a groundwater operable unit (OU) based on the VOC contamination. However, SAIC (1998) notes that localized high concentrations of chromium (up to 5,100 µg/L) and nickel (up to 3,800 µg/L) may indicate that metals contamination may still be a concern. The RG for both of these metals is 100 µg/L. The elevated chromium and nickel concentrations were detected in well LF014MW003, which is screened in the Navarro

Clay. Therefore, these data may not be representative of groundwater quality in the overlying alluvial aquifer. The areal extent and concentrations of total CAHs (tetrachloroethene [PCE] + TCE + 1,2-DCE + VC) in Site LF014 groundwater in April 1998 are shown on Figure 1.7.

### **1.6.3 Surface Water and Sediment**

As part of a preliminary investigation of Leon Creek surface water quality (HNUS, 1992c), surface water samples were collected at 5 to 14 sampling stations within Zone 1 during four separate sampling events. No organics were detected in any of the samples at concentrations exceeding MCLs. However, beryllium, cadmium, and lead were present in surface water samples at maximum concentrations of 22 µg/L, 20 µg/L, and 339 µg/L, respectively. The MCLs for beryllium and cadmium are 4 µg/L and 5 µg/L, respectively, and the federal action level for lead is 15 µg/L (USEPA, 1996). A risk assessment for adolescents playing in Leon Creek, assuming all contaminants in the creek were derived from Zone 1 groundwater, indicated no unacceptable health risks from exposure to surface water (HNUS, 1992c).

An ongoing semiannual monitoring program (CH2M Hill, 1999a and 1999b) evaluates the surface water, sediment, toxicological, and biological quality of Leon Creek. The following paragraphs summarize pertinent results from July through September 1998 (CH2M Hill, 1999a) and July 1999 (CH2M Hill, 1999b). The locations and identifications of Leon Creek sampling stations located near Site LF014 are shown on Figure 1.8. These stations are:

- KY030LC053, located in a long, deep pool upstream from the dam, along the southern shoreline;
- KY030LC018, located at the downstream end of the pool below the dam;
- KY030SP005, which is a groundwater seep draining clear water from the northern shoreline; and
- KY030LC015, located immediately north of the Military Drive bridge near the downstream boundary of Site LF014.

Analytical data for stations KY030LC042 and KY030OF014, shown on Figure 1.8, were not available in the two above-mentioned reports obtained by Parsons ES.

#### **1.6.3.1 Stream Flow Rate**

Historically, the flow rate within the 3.5-mile-long segment of Leon Creek at Kelly AFB is less than 10 cubic feet per second (cfs). However, during storm events, streamflows exceeding 10,000 cfs have occurred. The flow rates at station KY030LC018 in July 1998 and July 1999 were 0.23 cfs and 18.96 cfs, respectively. The estimated flow rate in Leon Creek approximately 400 feet downstream from the dam in January 2000 was approximately 5 cfs based on field observations made by Parsons ES. Several dry months preceded the January 2000 sampling event.





Not to Scale

**LEGEND**

● LEON CREEK SAMPLING STATION

**FIGURE 1.8**

**LEON CREEK SAMPLING STATIONS NEAR SITE LF014**

Site LF014 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

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The on-Base portion of Leon Creek was divided into four segments for the purpose of providing a more detailed calculation of the creek water budget (CH2M Hill, 1999a). The dividing line between segments 2 and 3 is the dam near station KY030LC018 (Figure 1.8). Segment 2 extends approximately 1 mile upstream from this station, and Segment 3 extends approximately 800 feet downstream from station KY030LC015. Streamflow measurements made on 21 July 1998 indicate a net loss of 0.86 cfs in Segment 2, and a net gain of 0.46 cfs in Segment 3, indicating groundwater inflow in Segment 3. The flow rate at KY030SP005 (located in Segment 3) was 0.114 cfs, and all man-made outfalls into Segment 3 were dry. Measurements made on 13 July 1999 indicate a net loss for Segment 2 of 3.65 cfs, and a net gain for Segment 3 of 10.41 cfs. According to CH2M Hill (1999b), the gain in Segment 3 measured in July 1999 was assumed to result primarily from groundwater inflow.

### 1.6.3.2 Surface Water Quality

In July through September 1998, the only VOC detected in surface water samples adjacent to Site LF014 occurred at station KY030SP005; PCE was detected at this groundwater seep at a concentration of 3 µg/L. The human health Texas Water Quality Standard (TWQS) for PCE is 5 µg/L, and no Texas aquatic life standard is available for this compound. The presence of PCE in water from the seep indicated that contaminated groundwater from Site LF014 was entering Leon Creek, but that concentrations were being rapidly reduced to nondetectable levels within the creek.

Surface water samples collected adjacent to Site LF014 in July 1999 had detectable concentrations of VOCs. However, all of the detected concentrations were below the established TWQs. VOCs detected in the creek (and the maximum concentration) included VC (0.9J µg/L), total 1,2-DCE (3 µg/L), and chloromethane (0.1 µg/L). At the surface seep (KY030SP005), TCE and total 1,2-DCE were detected at concentrations of 0.5J and 0.1J µg/L, respectively. The human health TWQS for TCE and VC are 5 and 2 µg/L respectively, and there are no Texas aquatic life standards for these compounds. It is interesting to note that the highest concentrations of 1,2-DCE and VC were detected at the upstream edge of Site LF014, indicating that VOCs discharging to the creek from Site LF014 were being rapidly attenuated via dilution and volatilization. No semivolatile organic compounds (SVOCs) were detected in the on-Base portion of Leon Creek during either the July through September 1998 or July 1999 sampling events.

One sample of surface water from Leon Creek was analyzed for VOCs as part of the January 2000 RPO evaluation sampling. Surface water sampling location KY030SW015 was established on the northern edge of Leon Creek, approximately 400 feet downstream from the dam (Figure 1.8). TCE, *cis*-1-2-DCE and VC were detected in this sample at concentrations of 0.82J µg/L, 2.34 µg/L, and 0.49J µg/L, respectively. These concentrations are similar to concentrations of VOCs detected during semiannual compliance sampling, as reported by CH2M Hill (1999a and 1999e). VOC concentrations detected in Leon Creek during January 2000 did not exceed the TWQs for the detected compounds.

A total of nine metals were detected in surface water samples collected adjacent to Site LF014 in July-September 1998 or July 1999. Of these metals, five (barium, calcium, magnesium, manganese, and vanadium) do not have a TWQS. Concentrations of the remaining four metals (antimony, arsenic, copper, and iron) did not exceed their

respective surface water standards. Concentrations of magnesium and calcium were reported to be similar to background concentrations, and are most likely a result of natural environmental conditions (CH2M Hill, 1999b).

Profiles of detected metal concentrations in surface water samples from upgradient station KY030LC053 to downgradient station KY030LC015 are shown on Figures 1.9 through 1.11. It should be noted that station KY030SP005, the groundwater seep along the bank of the creek, is not representative of surface water quality in Leon Creek. In general, the data indicate that groundwater discharging from Site LF014 is not significantly influencing the concentrations of metals in Leon Creek. However, possible exceptions to this observation include:

- Slight increases in dissolved barium concentrations within the reach of Leon Creek adjacent to Site LF014; and
- An increase in the total manganese concentration between KY030LC053 and KY030LC018 in during the July-September 1998 sampling event. Previous reports have noted the presence of elevated manganese concentrations in site groundwater.

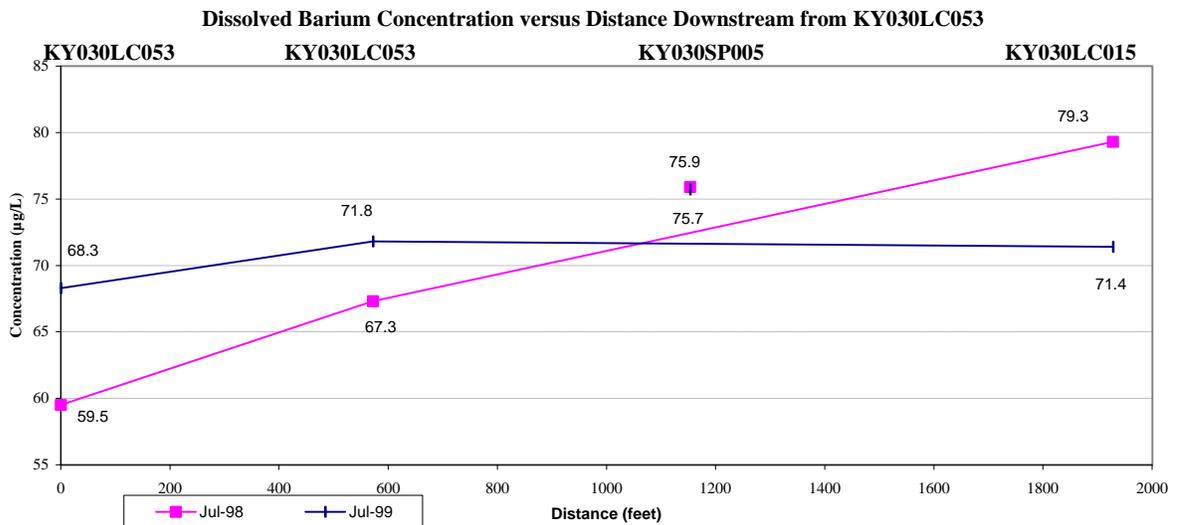
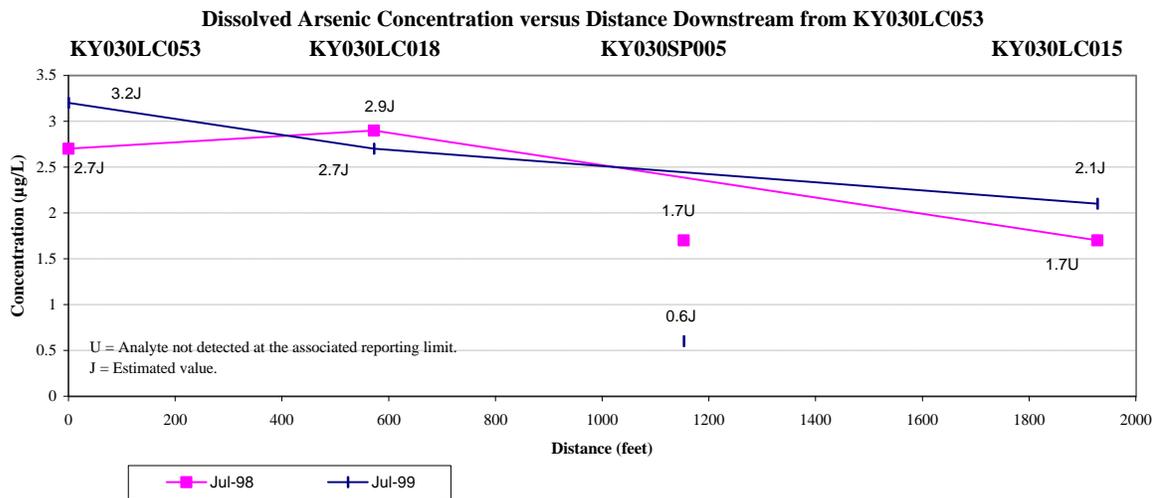
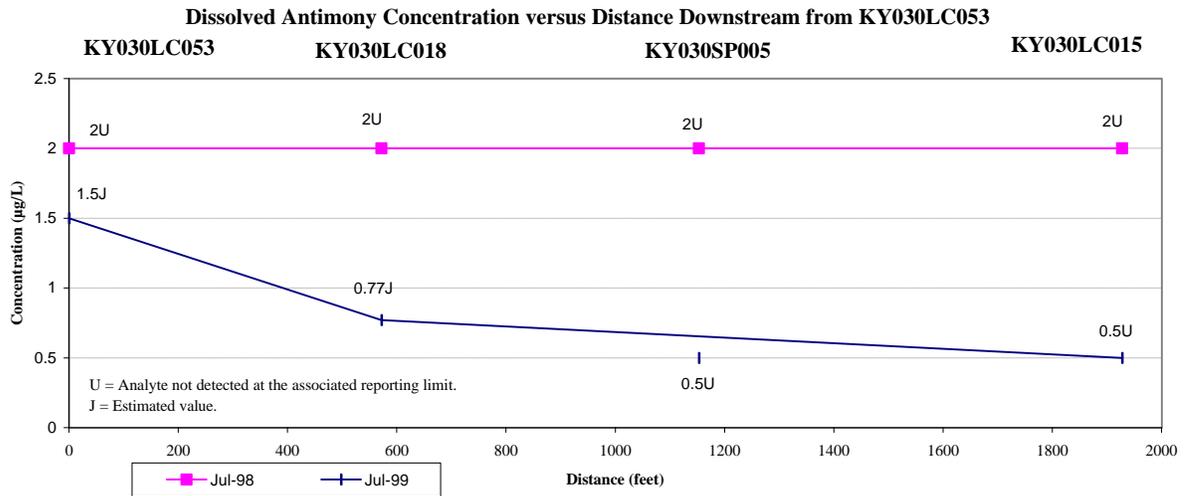
### 1.6.3.3 Sediment Quality

Only one VOC (toluene) was detected in Leon Creek sediments near Site LF014 during the July-September 1998 or July 1999 sampling events. Toluene was detected at KY030LC053 in July 1999 at a concentration of 3J µg/kg. However, sampling data indicate a significant increase in the number and concentration of detected SVOCs (primarily polynuclear aromatic hydrocarbons [PAHs]) at station KY030LC018 relative to KY030LC053 and KY030LC015. The SVOCs detected at this station generally have not been detected in Site LF014 groundwater, indicating that they do not result from groundwater discharge. KY030LC018 is located in a pool area near the downstream base of the dam. It is likely that suspended sediments settle out in this low-energy micro-environment, and that PAHs migrating in the creek as surface water dissolved compounds or adsorbed to suspended sediment particles preferentially accumulate at this location. Concentrations of the polychlorinated biphenyl (PCB) Arochlor 1254 exhibited a similar increase at station KY030LC018, most likely for the same reason described above for SVOCs. PCBs are not COCs in groundwater at Site LF014.

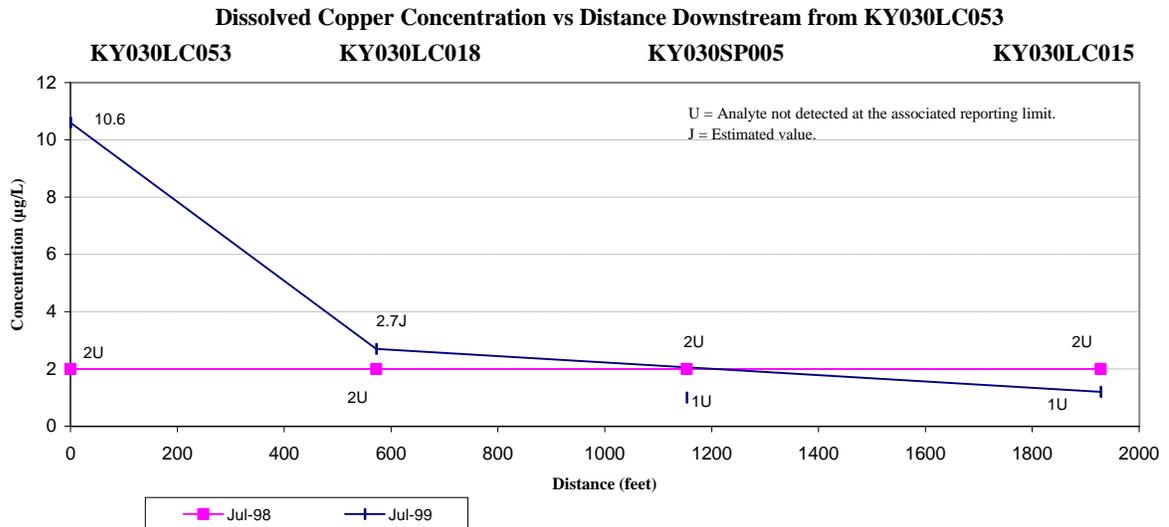
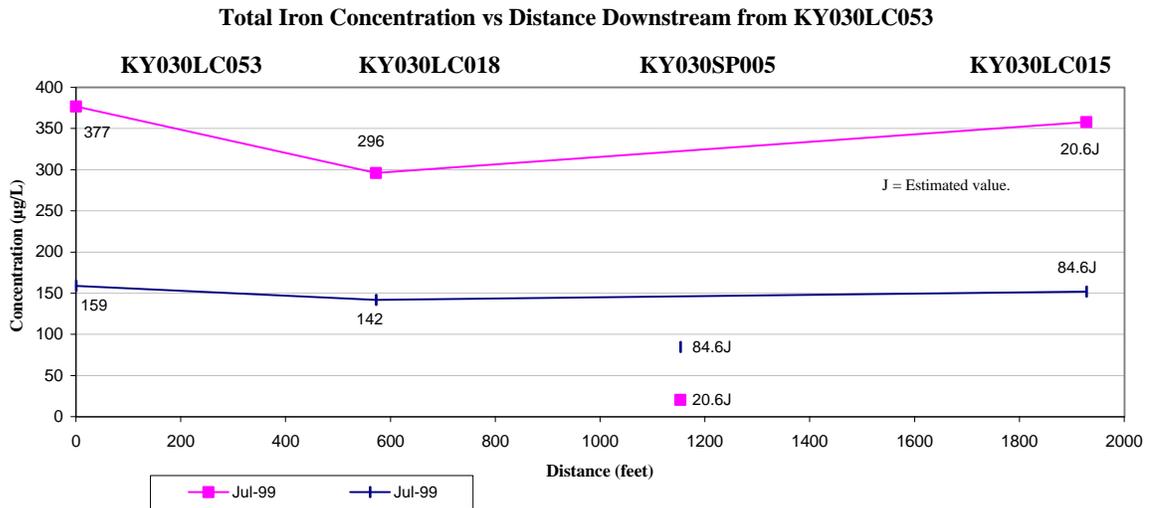
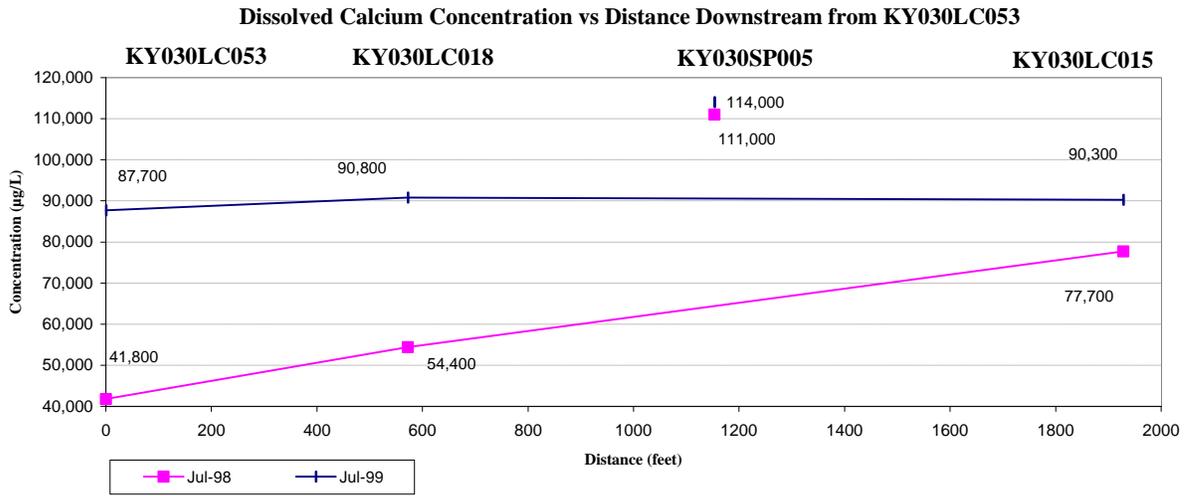
Total petroleum hydrocarbon (TPH) concentrations in sediment samples collected in July 1999 increased from 151 milligrams per kilogram (mg/kg) at KY030LC053 to 307 mg/kg at KY030LC018 to 334 mg/kg at KY030LC015. Similar increases are apparent in the July-September 1998 samples. However, available data indicate that petroleum hydrocarbons are not significant compounds of concern in Site LF014 groundwater. Therefore, it is unlikely that the increasing TPH concentrations in sediment samples between the upstream and downstream sampling stations are related to groundwater discharge.

Total concentrations of 16 metals were detected in sediment samples collected at the three above-mentioned sampling stations in July 1999. However, only concentrations of arsenic and chromium exceeded TWQS freshwater-stream sediment criteria. Total arsenic concentrations at the upstream, middle, and downstream stations were 10J mg/kg, 11.3J mg/kg, and 8.8J mg/kg, respectively. Total chromium concentrations at the

**FIGURE 1.9**  
**CONCENTRATIONS OF ANTIMONY, ARSENIC, AND BARIUM IN SURFACE WATER SAMPLES**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

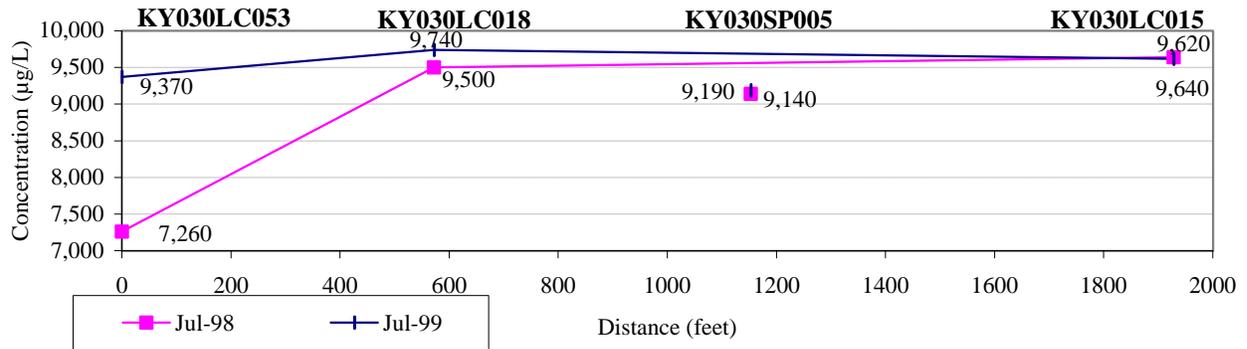


**FIGURE 1.10**  
**CONCENTRATIONS OF CALCIUM, IRON, AND COPPER IN SURFACE WATER SAMPLES**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

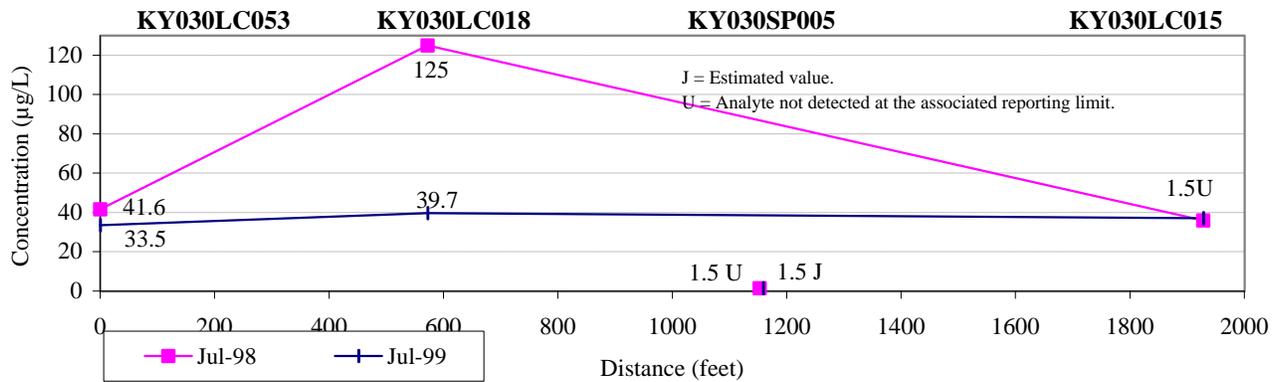


**FIGURE 1.11**  
**CONCENTRATIONS OF MAGNESIUM, MANGANESE, AND**  
**VANADIUM IN SURFACE WATER SAMPLES**  
**LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

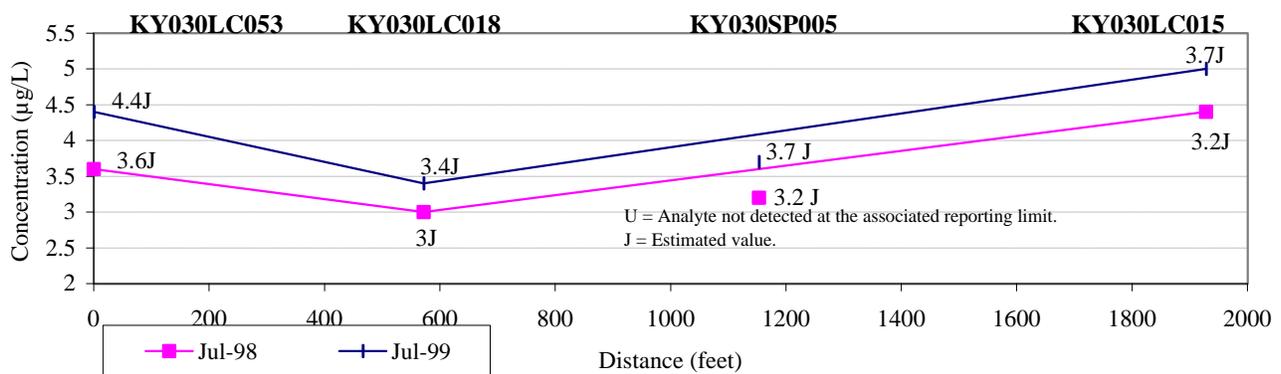
**Total Magnesium Concentration versus Distance Downstream from KY030LC053**



**Total Manganese Concentration versus Distance Downstream from KY030LC053**



**Total Vanadium Concentration versus Distance Downstream from KY030LC053**



upstream, middle, and downstream stations were 26.7J mg/kg, 37.6 mg/kg, and 34.7 mg/kg, respectively. The TWQS freshwater stream sediment criteria for arsenic and chromium are 6.9 mg/kg and 20 mg/kg, respectively. Total arsenic concentrations in Zone 1 ranged from 7.1J to 16.1J mg/kg, exceeding the TWQS value throughout the zone. Similarly, the total chromium concentration detected at station KY030LC023, located upstream from Site LF014, was 72.8J mg/kg. The total metal concentrations in sediment adjacent to Site LF014 do not indicate that sediment quality has been significantly impacted by groundwater discharge from the site.

#### **1.6.3.4 Overview of Leon Creek Impacts**

CH2M Hill (1999a and 1999b) concludes that Leon Creek has been impaired, although some of this impairment can be attributed to habitat characteristics; however, many of the biological indices show that water quality may contribute to this effect. Historical data indicate that the habitat quality at station KY030LC018 has been steadily degrading. The habitat quality is classified as "intermediate" based on data from the July 1999 sampling event. The degraded habitat quality for biological communities is mainly attributed to:

- The channeled nature of the stream,
- Lack of instream structure,
- Open canopy, and
- Lack of an in-depth tree/shrub riparian zone.

Other factors that may be contributing the impairment of Leon Creek at station KY030LC018 include:

- Stormwater runoff from the golf course containing nutrients and pesticides,
- Dying and degrading mats of filamentous algae, and
- Groundwater discharge from Site LF014

### **1.7 REGULATORY STATUS, REMEDIAL GOALS, AND INTERIM REMEDIAL ACTION**

Kelly AFB proposes to perform environmental restoration of Zone 1 in a manner consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and all ARARs. Kelly AFB also must perform restoration in compliance with their Resource Conservation and Recovery Act (RCRA) Permit and Compliance Plan (CP-50310). Policy established for the IRP is consistent with CERCLA guidelines, rules, regulations, and criteria. The State of Texas administers the solid and hazardous waste program that includes the TNRCC (1993) Risk-Reduction Standards (RRSs). The RRSs apply to the CERCLA process and are considered to be ARARs; therefore, RGs for groundwater were calculated in such a way as to be consistent with the Texas standards.

The groundwater FS for Zone 1 (HNUS, 1996) has been reviewed and approved by TNRCC. The FS also was submitted for public review and comment. A Proposed Plan describing the alternatives for the groundwater OU containing Site LF014 was prepared and presented for public review. The public review and comment period began in July

1995 and concluded in August 1995. During a public meeting held in July 1995, the alternatives were presented to the public. After evaluation and consideration of the public's comments, the Air Force, in cooperation with TNRCC, will prepare a ROD for Zone 1.

The FS for Zone 1 groundwater (HNUS, 1996) states that Kelly AFB intends to remediate Zone 1 groundwater under TNRCC (1993) RRS 3. RRS 3 involves conducting a baseline risk assessment (BRA) using site-specific data rather than standard default values. Site-specific cleanup levels are then back-calculated using the same algorithms used in the BRA and the following risk levels: carcinogenic risks of  $10^{-6}$  for single carcinogens and  $10^{-4}$  for cumulative risk, and a noncarcinogenic hazard quotient of 1. Kelly AFB has control over groundwater consumption within its boundaries, and currently there are no drinking water wells completed within the surficial aquifer on the Base. In addition, the Air Force has the means to assure that no such wells will be installed in the future. However, in order to provide a conservative basis for the selection of a remedial alternative, and because the surficial aquifer is technically classified as a potential drinking water source, RGs for groundwater were developed considering residential ingestion of groundwater. RGs were determined for each COC according to the following hierarchy:

1. Nonzero maximum contaminant level goal (MCLG) promulgated under the Safe Drinking Water Act;
2. MCL promulgated under the Safe Drinking Water Act;
3. Practical quantitation limit (PQL) if higher than the calculated risk-based concentration (RBC);
4. Carcinogenic or noncarcinogenic RBC, whichever is lower; and
5. No value assigned as a RG if an RBC cannot be calculated due to lack of chemical-specific data and there is no non-zero MCLG or MCL.

For each of the Zone 1 IRP sites analyzed during the soils CMS (CH2M Hill, 1999d), site-specific soil direct-contact and GWP standards were developed as preliminary RGs for those chemicals of potential concern (COPCs) exceeding TNRCC RRS 2 industrial GWP criteria. The CMS compared COPCs that exceeded background concentrations (TNRCC [1993] RRS 1) to TNRCC RRS 2 criteria, and evaluated them in the human health BRA.

An FFS for selecting an appropriate interim remedial action for Zone 1 groundwater was finalized in 1992 (HNUS, 1992b). Based on the results of the FFS, construction of 14 groundwater extraction wells and a treatment system were installed in 1993. The system was designed using a two-dimensional (2-D) numerical groundwater flow model. The original model was presented in the FFS, and was modified slightly in the final FS (HNUS, 1996). Capture-zone analysis has also been conducted during a Base-wide remedial assessment using a 3-D model (USAF, 1998). A new model was presented by SAIC (1998) that reflects the latest site hydrogeologic information to show the capture zone of the current extraction system and a proposed modification.

## **1.8 REMEDIATION SYSTEM DESCRIPTION**

The current groundwater extraction system at Site LF014 consists of a linear array of 14 pumping wells (LF014RW032 through LF014RW045) located approximately 50 to 60 feet northeast of Leon Creek (Figure 1.5). The well spacing parallel to the creek ranges from 70 to 110 feet and averages approximately 90 feet. The Site LF014 system was designed to pump at 3.5 gallons per minute (gpm) per well (Weston, 1995), and the pumps are rated at approximately 5 gpm based on as-built information from Kelly AFB. The 14-well system commenced operation in 1993 and is still operating. Based on pumping tests, the sustainable pumping rates vary from less than 1 gpm to greater than 740 gpm (SAIC, 1998). Based on O&M records, the maximum pumping rates achieved vary from 0.1 gpm to 5.1 gpm. The average total system flow rate in 1997 was approximately 20 gpm. The combined flow is treated in a newly installed treatment system employing ultra-violet light oxidation (UVOX).

The results of the SAIC (1998) evaluation of the effectiveness of the existing recovery system are described in Section 1.4.7. The revised groundwater model prepared for the 1998 system evaluation indicated that the current system is providing little containment of the VOC groundwater plume. Based on SAIC's (1998) findings, the Base plans to replace the existing well system at Site LF014 with a groundwater extraction trench. The trench design and installation are planned for years 2000 and 2001, respectively. A preliminary proposed trench location is shown on Figure 1.12. In addition, the Base plans to install a soil vapor extraction (SVE) system in the northwestern portion of the landfill and regrade/revegetate the landfill to minimize infiltration of precipitation (also shown on Figure 1.12).

## **1.9 MONITORING PROGRAM DESCRIPTION**

Selected site monitoring wells are sampled annually for compliance monitoring purposes. These wells are listed in Table 1.1. Samples are analyzed for VOCs, SVOCs, total metals, pesticides/PCBs, and cyanide. In addition, two extraction wells (not the same wells every time) and the treatment plant influent are sampled annually, typically in May. These samples are analyzed for VOCs, SVOCs, metals, PCBs and pesticides, sulfide, and cyanide.

FILE N. \\S:\E\MS\DR\POKELLY\MAPS\CONCEPTS\FIGURE 1.12.MXD (6/11/04) TIME: 11:00

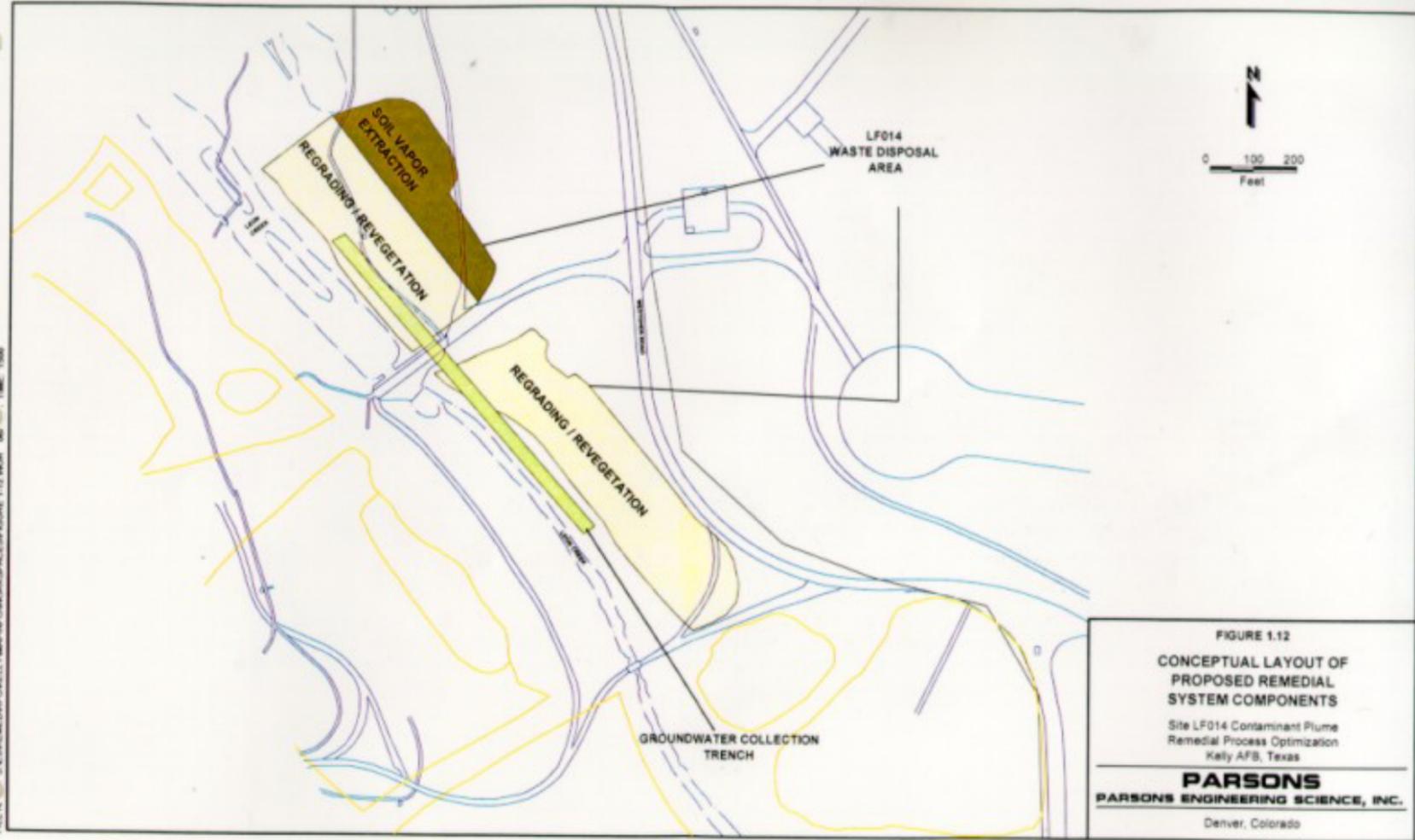


FIGURE 1.12  
CONCEPTUAL LAYOUT OF  
PROPOSED REMEDIAL  
SYSTEM COMPONENTS  
Site LF014 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas  
**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.  
Denver, Colorado

**TABLE 1.1  
LONG-TERM MONITORING WELLS  
SITE LF014 CONTAMINANT PLUME  
REMEDIAL PROCESS OPTIMIZATION  
KELLY AFB, TEXAS**

Well Number	Monitoring Objective
SS035MW010	Background
LF013MW005	Corrective Action Observation
LF014MW003	Point of Compliance
LF014MW004	Corrective Action Observation
LF014MW005	Point of Compliance
LF014MW006	Corrective Action Observation
LF014MW009	Corrective Action Observation
LF014MW012	Point of Compliance
LF014MW026	Corrective Action Observation
LF014MW027	Point of Compliance
LF014MW028	Corrective Action Observation
LF014MW030	Point of Compliance

## **SECTION 2**

### **SUPPLEMENTAL SITE CHARACTERIZATION ACTIVITIES**

Supplemental site characterization activities were performed to achieve the RPO evaluation objectives listed in Section 1. These activities, which occurred from 24 to 29 January 2000, are described in the following subsections.

#### **2.1 TEMPORARY MONITORING WELL AND PIEZOMETER INSTALLATION**

A total of 19 temporary monitoring wells (TWs) and two temporary piezometers were installed to facilitate collection of groundwater samples and/or water-level measurements. The locations of these wells and piezometers are shown on Figure 2.1, and well construction details are contained in Table 2.1. The project work plan (Parsons ES, 1999b) stated that these wells would be installed along a northwest/southeast-trending line located approximately 25 feet northeast of (upgradient from) the line of existing groundwater recovery wells (RWs). However, a site visit performed subsequent to release of the work plan indicated that there were two landfill trenches southwest of (downgradient from) this line. Therefore, the majority of the wells were installed along a northwest/southeast-trending line coincident with the line of groundwater RWs for the following reasons:

- To facilitate collection of groundwater samples downgradient from the landfill to the extent feasible, but not hydraulically downgradient from the RWs; and
- To assess the degree to which dissolved VOCs were migrating past the line of RWs.

Three of the TWs (LF014TW115, 117, and 118) were installed along the originally proposed line upgradient from the RWs due to the potential presence of a subsurface pipeline near the RWs.

The wells and piezometers were installed using a direct-push rig (Strataprobe®) by TEG-South of Houston, Texas. The Strataprobe® was used to advance a 1.75-inch-diameter borehole to the top of the Navarro Clay. Isolation casing was advanced concurrently with the drive rods to prevent caving of the borehole walls prior to well installation. One soil sample was collected from each borehole using a split-barrel sampler to confirm that the Navarro Clay had been reached.

After the borehole had been advanced to the Navarro Clay, the drive rods were removed, and a TW was installed through the isolation casing. The TWs were constructed using 1-inch inside-diameter, polyvinyl chloride (PVC) screen and riser pipe.



**TABLE 2.1**  
**CONSTRUCTION DATA FOR TEMPORARY WELLS AND PIEZOMETERS**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Well Identification	Northing	Easting	Well Completion Date	Screen Length (feet)	Total Depth (feet bgs) <sup>a/</sup>	Screened Interval (feet bgs)	Top of Casing Elevation	Well Casing Stick-Up (feet)	Ground Elevation
LF014TW102	558,355.4	2,131,421	1/24/2000	10	16.0	6.0 - 16.0	632.62	1.5	631.1
LF014TW103	558,373.5	2,131,403	1/24/2000	10	15.3	5.3 - 15.3	633.14	1.6	631.6
LF014TW104	558,403.8	2,131,374	1/25/2000	10	17.2	7.2 - 17.2	632.99	1.6	631.4
LF014TW105	558,419.9	2,131,359	1/25/2000	10	18.3	8.3 - 18.3	632.95	1.8	631.2
LF014TW106	558,436.6	2,131,342	1/25/2000	10	21.2	11.2 - 21.2	632.66	1.6	631.1
LF014TW107	558,466.4	2,131,312	1/25/2000	10	19.0	9.0 - 19.0	628.37	1.3	627.1
LF014TW108	558,486.2	2,131,294	1/25/2000	10	19.3	9.3 - 19.3	629.06	0.9	628.1
LF014TW109	558,507.4	2,131,274	1/25/2000	10	18.2	8.2 - 18.2	630.60	2.0	628.6
LF014TW110	558,537.9	2,131,244	1/25/2000	10	19.4	9.4 - 19.4	630.24	0.8	629.5
LF014TW111	558,797.7	2,130,959	1/26/2000	10	18.5	8.5 - 18.5	628.63	1.4	627.2
LF014TW112	558,744.3	2,131,014	1/26/2000	10	18.7	8.7 - 18.7	628.10	1.5	626.6
LF014TW113	558,728.7	2,131,030	1/26/2000	10	18.5	8.5 - 18.5	629.84	1.7	628.2
LF014TW114	558,711.8	2,131,047	1/26/2000	10	18.6	8.6 - 18.6	631.65	1.4	630.2
LF014TW115	558,677.2	2,131,133	1/26/2000	10	18.5	8.5 - 18.5	631.98	1.3	630.6
LF014TW116	558,621.5	2,131,152	1/26/2000	5	16.3	11.3 - 16.3	630.38	1.2	629.2
LF014TW117	558,627.3	2,131,187	1/26/2000	10	19.3	9.3 - 19.3	631.74	0.9	630.8
LF014TW118	558,610.2	2,131,205	1/27/2000	5	18.8	13.8 - 18.8	631.84	1.3	630.5
LF014TW119	558,776.3	2,130,975	1/27/2000	10	18.5	8.5 - 18.5	628.46	1.6	626.9
LF014TW120	558,516.2	2,131,548	1/27/2000	5	17.8	12.8 - 17.8	642.98	2.4	640.6
LF014PZ128	558,657.9	2,131,484	1/27/2000	5	11.0	6.0 - 11.0	640.87	1.7	639.2
LF014PZ129	558,432.7	2,131,712	1/27/2000	10	19.0	9.0 - 19.0	642.66	0.9	641.7

<sup>a/</sup> bgs = below ground surface.

A cap was installed at the bottom of each well screen. After installation of the well screen and riser pipe, the isolation casing was removed, and the formation was allowed to collapse against the well casing. A 1-foot-thick bentonite plug was installed in the annular space at the top of the well to prevent introduction of foreign material (e.g., dirt, grass, precipitation) into the annular space.

## **2.2 GROUNDWATER SAMPLING AND ANALYSIS**

Groundwater samples were collected from 18 of the 19 newly installed TWs. LF014TW111, at the northwest end of the sampling line, was not sampled. In addition, samples were collected from five previously installed monitoring wells, one former pumping well (LF014PW046), six RWs (from the piezometers installed in the annular spaces of the RW boreholes) and directly from one groundwater RW. All but one of the samples was collected using a peristaltic pump with dedicated high-density polyethylene and silicone tubing. The sample collected directly from the RW was obtained from the spigot located in the RW vault. Prior to sample collection, each well was purged at a low flow rate (micropurging technique) until the pH, electrical conductivity, temperature, dissolved oxygen (DO), and oxidation/reduction potential (ORP) of the purged groundwater stabilized. Groundwater samples were collected immediately following well purging.

The analytical program for groundwater samples is summarized in Tables 2.2 and 2.3. All groundwater samples were analyzed for VOCs using USEPA Method SW8260B. The compounds targeted for analysis using this method were those listed in the Quality Assurance Project Plan (QAPP) prepared for Kelly AFB by CH2M Hill (1999b). However, five additional compounds not listed in the QAPP also were targeted for analysis using Method SW8260B. These compounds include naphthalene; 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB; 1,2-dichlorobenzene (1,2-DCB), and 1,4-DCB. Naphthalene and the TMBs were targeted for analysis to provide additional information on the presence of petroleum hydrocarbons in the landfill that can act as electron donors during microbially mediated biodegradation of anthropogenic organic compounds. The DCBs were targeted for analysis because they have been detected in site groundwater during previous sampling events. The fixed-base laboratory analyses were performed by DHL Analytical in Round Rock, Texas.

In addition to VOCs, selected groundwater samples were analyzed for a suite of physical and geochemical parameters to facilitate an assessment of the degree to which the groundwater environment is conducive to biodegradation of dissolved CAHs. These parameters and their respective analytical methods are listed in Table 2.2, and the samples analyzed for these parameters are summarized in Table 2.3. The project work plan (Parsons ES, 1999b) stated that the natural attenuation sampling would be focused southeast of well LF014MW040 because natural attenuation may effectively reduce the relatively low dissolved contaminant concentrations in this area to levels that would not pose a threat to human health or the environment. However, the natural attenuation indicator parameter samples were distributed more evenly throughout the groundwater plume to provide a more balanced assessment of natural attenuation in site groundwater.

**TABLE 2.2**  
**ANALYTICAL PROTOCOL FOR GROUNDWATER SAMPLES**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Analyte	Method	Field (F) or Analytical Laboratory (L) <sup>a/</sup>
Ferrous Iron (Fe <sup>+2</sup> )	Colorimetric, Hach Method 8146	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131	F
Sulfate	Colorimetric, Hach Method 8051	F
Alkalinity (Carbonate [CO <sub>3</sub> <sup>-2</sup> ] and Bicarbonate [HCO <sub>3</sub> <sup>-1</sup> ])	Titrimetric, Hach Method 8221	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Oxidation/Reduction Potential	Direct-reading meter	F
Dissolved Oxygen	Direct-reading meter	F
pH	Direct-reading meter	F
Conductivity	Direct-reading meter	F
Temperature	Direct-reading meter	F
Nitrate + Nitrite [as Nitrogen (N)]	USEPA SW9056	L
Ammonia (dissolved gas in water)	Chemetrics Method 1510	F
Chloride	USEPA SW9056	L
Methane, Ethane, Ethene	USEPA M2720C	L
Dissolved Organic Carbon	USEPA SW9060	L
Total Organic Carbon	USEPA SW9060	L
VOCs <sup>b/</sup>	USEPA SW8260	L

<sup>a/</sup> Fixed-base laboratory analyses performed by DHL Analytical of Round Rock, Texas.

<sup>b/</sup> VOCs - volatile organic compounds.

**TABLE 2.3  
GROUNDWATER ANALYSES BY SAMPLING LOCATION  
SITE LF014 CONTAMINANT PLUME  
REMEDIAL PROCESS OPTIMIZATION  
KELLY AFB, TEXAS**

Sample Location	Analytes <sup>a/</sup>																		
	VOCs	TOC	DOC	Chloride	Nitrate + Nitrite	Ammonia	Ferrous Iron	Hydrogen Sulfide	Sulfate	Total Alkalinity	Carbon Dioxide	Dissolved Oxygen	Redox Potential	pH	Temperature	Conductivity	Methane	Ethane	Ethene
LF014MW022	X											X	X		X	X			
LF014MW029	X						X	X	X	X	X	X	X		X	X			
LF014MW076		X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
LF014MW078		X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
LF014MW082		X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
LF014PW046		X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
LF014RW033	X		X																
LF02RW033PZ	X											X	X		X	X			
LF014RW035PZ	X											X	X		X	X			
LF014RW036PZ	X					X	X	X	X	X	X	X	X		X	X			
LF014RW037PZ	X											X	X		X	X			
LF014RW038PZ	X											X	X	X	X	X			
LF014RW039PZ	X											X	X	X	X	X			
LF014TW102	X	X		X	X		X			X	X	X	X	X	X	X	X	X	X
LF014TW103	X																		
LF014TW104	X																		
LF014TW105	X																		
LF014TW106	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
LF014TW106-Dup <sup>b/</sup>	X																		
LF014TW107	X											X	X	X	X	X			
LF014TW108	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
LF014TW109	X											X	X	X	X	X			
LF014TW110	X											X	X	X	X	X			
LF014TW112	X											X	X	X	X	X			
LF014TW113	X						X	X	X	X	X	X	X	X	X	X			
LF014TW114	X											X	X	X	X	X			
LF014TW114-Dup <sup>b/</sup>	X																		
LF014TW115	X											X	X	X	X	X			
LF014TW116	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
LF014TW117	X											X	X	X	X	X			
LF014TW118	X																		
LF014TW119	X					X	X	X	X	X	X	X	X		X	X			
LF014TW120	X	X		X	X		X	X	X	X	X	X	X		X	X	X	X	X
KY030SW015 <sup>c/</sup>	X																		

<sup>a/</sup> VOCs = volatile organic compounds, TOC = total organic carbon, DOC = dissolved organic carbon.

<sup>b/</sup> Dup = Duplicate sample.

<sup>c/</sup> Surface water sample.

## **2.3 SURFACE WATER SAMPLING AND ANALYSIS**

One surface water sample was collected in Leon Creek at the location shown on Figure 2.1. The purpose for collecting this sample was to obtain additional information regarding the degree to which discharge of the dissolved CAH plume to Leon Creek is impacting surface water quality. The sample was analyzed for VOCs using USEPA Method SW8260B. The sample collection procedure involved submerging a decontaminated glass beaker in the creek, then carefully transferring the sample to the sample bottle by pouring it down the inner walls of the sample bottle to minimize aeration of the sample.

## **2.4 WATER-LEVEL MEASUREMENTS**

Water-level elevations were measured in all temporary and permanent wells at the site on 29 January 2000. In addition, water levels in the piezometers screened in the RW filter packs were measured. The measurements were made to the nearest 0.01-foot using an oil/water interface probe.

## **2.5 SURVEYING**

The horizontal locations and elevations of all TWs and piezometers installed during the field program were surveyed by Macias and Associates, Inc. of Austin, Texas. Existing wells LF014RW032 and LF014RW039 were used as benchmarks for determining the coordinates of the newly installed TWs. The re-surveyed coordinates for these wells provided by SAIC (1998) were used as starting points. The coordinates for LF014RW032 used during the survey data reduction are 558811 (northing) and 2130941 (easting). The coordinates for LF014RW039 are 558388 (northing) and 2131388 (easting). The elevations of the tops of the TW and piezometer casings are referenced to the top-of-casing elevation of 627.50 for LF014RW032 (SAIC, 1998). Horizontal coordinates and elevations were surveyed to the nearest 0.1 foot and 0.01 foot, respectively.

## **2.6 WELL ABANDONMENT**

The TWs and piezometers were abandoned at the conclusion of the field program. Abandonment involved pulling the PVC screen and riser pipe out of the borehole, and filling the borehole to the ground surface with bentonite chips.

## **2.7 EQUIPMENT DECONTAMINATION**

Upon arrival at the Base, the Strataprobe® and associated equipment were decontaminated at the Base Environmental Process Control Facility (EPCF) using a high-pressure wash. Between boreholes, all downhole Strataprobe® equipment (e.g., rods, drive shoe, and soil sampling barrel) was cleaned using the following procedures:

- Scrub with a potable water/phosphate-free detergent mix;
- Deionized water rinse; and
- Air dry.

Dedicated tubing was used during groundwater sampling activities, eliminating the need for decontamination of this sampling equipment. The glass beaker used to collect the surface water sample was decontaminated using the above-listed procedures. The oil/water interface probe was decontaminated between each use using the procedures described in Section 11.3 of the Base-wide Sampling and Analysis Plan (SAP) (CH2M Hill, 1999c).

## **2.8 INVESTIGATION-DERIVED WASTES**

All water derived from decontamination and well purging activities was containerized and disposed of at the on-Base wastewater treatment plant (WWTP). Approximately 5 gallons of waste soils was generated as a result of soil sampling activities. These soils were placed in properly labeled containers provided by the Base, and turned over to the Base for disposal. The TW and piezometer screen and riser pipe removed during abandonment activities were steam-cleaned at the Base EPCF, and removed from the Base by the drilling subcontractor, TEG-South.

## **SECTION 3**

### **REVIEW OF CONCEPTUAL SITE MODEL**

A conceptual site model (CSM) provides a summary of the physical and chemical characteristics of a site. This is the baseline from which personnel responsible for the site can make informed remedial decisions. The CSM should be continually updated based on the most recent operating and monitoring data. This section provides clarification and refinement of the CSM.

#### **3.1 AQUIFER THICKNESS**

The geologic cross-section presented on Figure 1.5 indicates a gently undulating Navarro Clay surface. During installation of the TWs in January 2000, an attempt was made to determine the depth of the Navarro Clay surface at each well location by observing the drilling action. When the drilling action indicated that the overlying gravel zone had been penetrated and the clay had been reached, a sample of the clay was obtained for confirmatory purposes; however, these samples were not necessarily collected at the top of the clay.

A revised cross-section depicting the TWs and an updated interpretation of the Navarro Clay surface configuration along the cross-section line is shown on Figure 3.1. Temporary wells LF014TW015, TW017, and TW018, located approximately 25 feet northeast of the main cross-section line, were projected onto the cross-section. The revised cross-section indicates that the Navarro Clay surface, which is present at an average depth of approximately 18 feet bgs, undulates to a greater degree than depicted on Figure 1.5. Therefore, if a cutoff trench is constructed parallel to the creek in the future, care should be taken to ensure that it is consistently keyed into the Navarro Clay to prevent underflow of dissolved contaminants.

#### **3.2 JANUARY 2000 VOC SAMPLING RESULTS**

As described in Section 2.2, all groundwater samples collected in January 2000 were analyzed for VOCs. A summary of analytical results for detected compounds is shown in Table 3.1, and analytical results for TCE, 1,2-DCE, and VC are shown on Figures 3.2 and 3.3. Appendix F provides the complete results for VOCs in samples collected in January 2000. All but one of the 27 sampling stations listed on Table 3.1 were located along or near a line parallel to and approximately 60 feet northeast of Leon Creek, near the downgradient edge of the landfill. Sample station numbers ending with "PZ" indicate that the sample was collected from the piezometer screened within the filter pack of the groundwater RW. Detected concentrations of TCE, *cis*-1,2-DCE, and VC along the sampling line near Leon Creek ranged up to 168 µg/L, 424 µg/L, and 341 µg/L, respectively. The continued presence of elevated CAH concentrations between the



**TABLE 3.1**  
**VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER, JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Sample Location	PCE <sup>af</sup> (µg/L) <sup>cf</sup>	TCE <sup>af</sup> (µg/L)	<i>cis</i> -1,2-DCE <sup>af</sup> (µg/L)	<i>trans</i> -1,2-DCE (µg/L)	Total 1,2-DCE <sup>bf</sup> (µg/L)	1,1-DCE (µg/L)	VC <sup>af</sup> (µg/L)	1,1,2-TCA <sup>af</sup> (µg/L)	1,2-DCB <sup>af</sup> (µg/L)	1,4-DCB (µg/L)	Chloro- benzene (µg/L)	Benzene (µg/L)	Acetone (µg/L)
<b>Groundwater</b>													
LF014MW022	1 U <sup>d/</sup>	1 U	13.6	3.03	16.6	1 U	76.9	1 U	3.26	1.86	6.27	0.22 J <sup>cf</sup>	10 U
LF014MW029	1 U	18.7	60.6	1.3	61.9	1 U	0.4 J	1 U	1 U	1 U	1 U	1 U	10 U
LF014RW033	1 U	146	244	4.48	248	0.65 J	28.5	1 U	0.31 J	0.68 J	23.3	1 U	10 U
LF014RW033PZ <sup>f/</sup>	1 U	1.6	4.88	1 U	5.4	1 U	0.58 J	1 U	1 U	1 U	2	1 U	10 U
LF014RW035PZ	0.32 J	76.1	212	2.67	215	0.38 J	9.57	1 U	1 U	1 U	7.88	0.22 J	10 U
LF014RW036PZ	1 U	0.72 J	77.5	7.67	85.2	1 U	32.4	1 U	2.08	1.76	14.6	1.09	14.1
LF014RW037PZ	1 U	40.7	128	7.1	135	0.46 J	20.6	1 U	3.81	2.33	10.8	1 U	10 U
LF014RW038PZ	1 U	0.35 J	181	12.1	193	0.68 J	64.5	1 U	13.3	6.36	16.8	0.37 J	10 U
LF014RW039PZ	1 U	1 U	37.3	5.96	43.3	1 U	7.82	1 U	1 U	1 U	1 U	1 U	10 U
LF014TW102	1 U	0.39 J	77.5	14.4	91.9	0.32 J	105	1 U	2.19	2.05	12.1	0.68 J	10 U
LF014TW103	1 U	1.12	84.2	16.4	101	0.14 J	88.6	1 U	0.34 J	0.75 J	6.69	0.81 J	10 U
LF014TW104	1 U	1 U	32.1	6.33	38.4	1 U	1.06	1 U	1 U	1 U	1.3	0.56 J	2820
LF014TW105	1 U	1 U	4.73	16.3	21.0	0.16 J	63.4	1 U	3.5	2.33	22.8	0.48 J	550
LF014TW106	1 U	0.12 J	5.39	31	36.4	1.03	339	1 U	12.9	8.21	52.6	1.61	10 U
LF014TW106-Dup <sup>g/</sup>	1 U	0.12 J	5.41	31.5	36.9	1.02	341	1 U	13	8.32	53.9	1.63	10 U
LF014TW107	1 U	1 U	89	9.87	98.9	0.28 J	71.2	1 U	4.89	2.86	12.7	0.37 J	16.6
LF014TW108	1 U	1 U	203	22	225	0.61 J	85.9	1 U	8.83	4.33	13.4	0.45 J	10 U
LF014TW109	1 U	1 U	203	20.4	223	0.58 J	73.9	1 U	4.87	2.86	12.2	0.43 J	10 U
LF014TW110	1 U	1 U	232	35.1	267	0.61 J	59.3	1 U	1 U	0.77 J	8.02	0.37 J	10 U
LF014TW112	1 U	22.1	18.5	0.65 J	19.2	1 U	1.51	1 U	0.33 J	0.79 J	9.96	1 U	13.9
LF014TW113	1 U	31.6	35.4	1.2	36.6	1 U	3.53	1 U	1 U	0.71 J	16.2	1 U	10 U
LF014TW114	1 U	1.11	2.55	1 U	3.05	1 U	1 U	1 U	1 U	1.13	15.4	1 U	10 U
LF014TW114-Dup	1 U	0.76 J	1.96	1 U	2.46	1 U	1 U	1 U	1 U	1	14	1 U	10 U
LF014TW115	0.5 J	168	424	7.59	432	0.8 J	1.48	1 U	1 U	1 U	1 U	1 U	34
LF014TW116	1 U	43.9	225	15.4	240	0.4 J	5.36	1 U	12.6	5.37	15.6	0.8 J	14.7
LF014TW117	0.36 J	133	414	9.98	424	1.02	3.21	1 U	1 U	1 U	0.65 J	1 U	10 U
LF014TW118	0.14 J	67	340	19.3	359	0.68 J	4.5	1 U	1 U	1 U	1.08	1 U	10 U

**TABLE 3.1 (Continued)**  
**VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER, JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Sample Location	PCE <sup>a/</sup> (µg/L) <sup>c/</sup>	TCE <sup>a/</sup> (µg/L)	<i>cis</i> -1,2-DCE <sup>a/</sup> (µg/L)	<i>trans</i> -1,2-DCE (µg/L)	Total 1,2-DCE <sup>b/</sup> (µg/L)	1,1-DCE (µg/L)	VC <sup>a/</sup> (µg/L)	1,1,2-TCA <sup>a/</sup> (µg/L)	1,2-DCB <sup>a/</sup> (µg/L)	1,4-DCB (µg/L)	Chloro- benzene (µg/L)	Benzene (µg/L)	Acetone (µg/L)
<b>Groundwater</b>													
LF014TW119	1 U	0.88 J	31.4	0.53 J	32	1 U	3.8	1 U	1 U	1 U	1.66	1 U	10 U
LF014TW120	2.55	488	491	22.2	513	0.87 J	18.2	0.34 J	0.85 J	0.33 J	0.69 J	1 U	10 U
<b>Surface Water</b>													
KY030SW015	1 U	0.82 J	2.34	1 U	2.84	1 U	0.49 J	1 U	1 U	1 U	1 U	1 U	10 U

<sup>a/</sup> PCE = tetrachloroethene, TCE = trichloroethene, DCE = dichloroethene, VC = vinyl chloride, TCA = trichloroethane, DCB = dichlorobenzene.

<sup>b/</sup> Total 1,2-DCE = Sum of *cis* and *trans*-1,2-DCE; where analyte not detected one-half the detection limit is used in summation

<sup>c/</sup> µg/L = micrograms per liter.

<sup>d/</sup> U = Analyte not detected at the indicated detection limit.

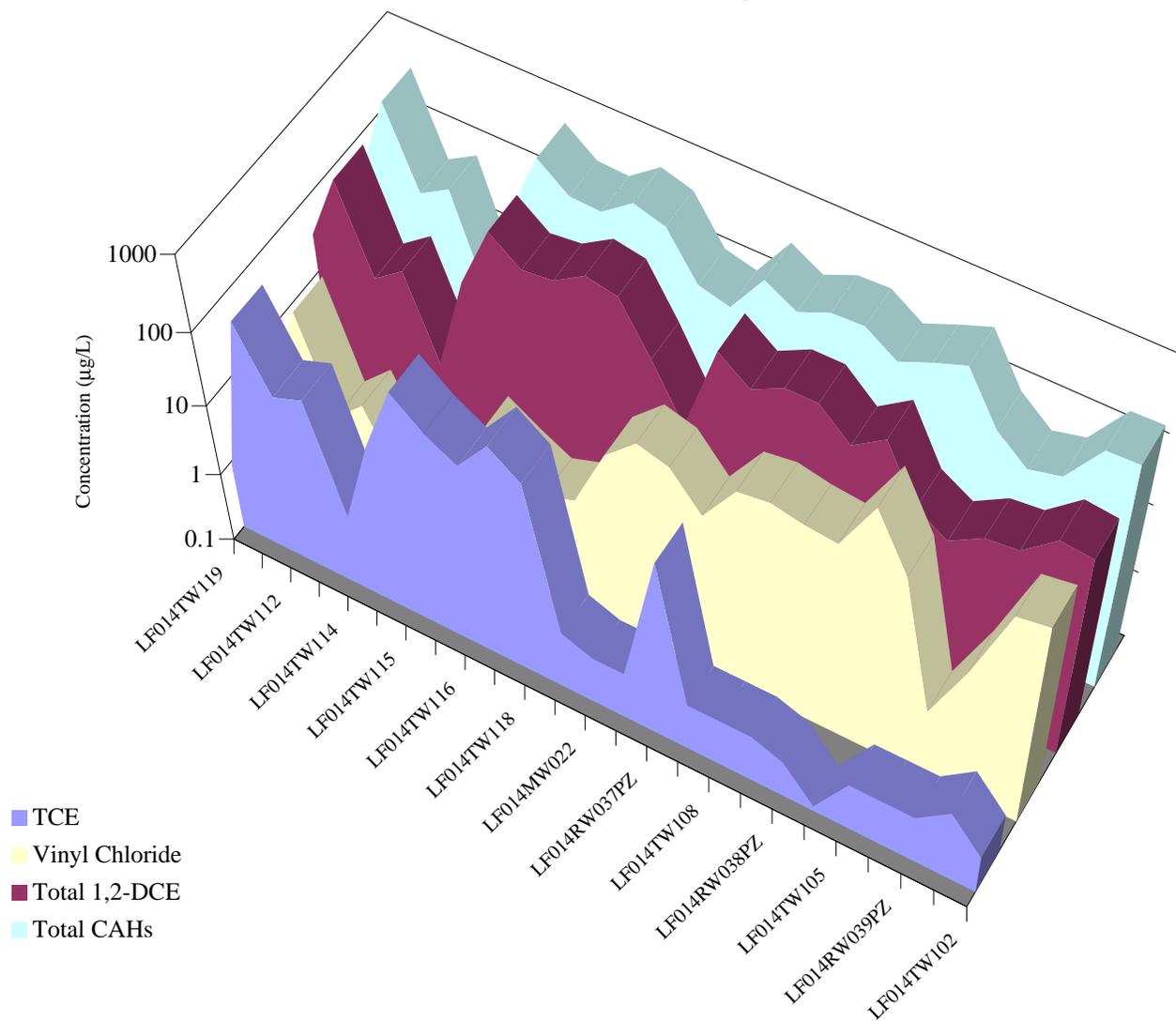
<sup>e/</sup> J = Concentration is estimated.

<sup>f/</sup> PZ indicates that the recovery well was sampled from its associated piezometer.

<sup>g/</sup> Dup = Duplicate sample.



**FIGURE 3.3**  
**CAH CONCENTRATIONS ALONG SAMPLING LINE IN JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**



extraction well line and the creek (e.g., wells LF014MW084 and LF014MW012) support the observation that the extraction well system is providing incomplete containment of the CAH plume.

The relatively elevated TCE concentrations along the northwest portion of the sampling line (LF014RW033 to LF014TW118) are indicative of a continuing source of TCE in the landfill. Concentrations of the reductive dehalogenation daughter product VC detected in this area were relatively low, suggesting incomplete microbial transformation of TCE and 1,2-DCE. In contrast, lower TCE concentrations detected southeast of LF014TW118 suggest a decreasing source. VC concentrations in this area were higher, perhaps indicating an older plume with more complete microbial transformation of TCE and 1,2-DCE. As shown in Section 3.5.4, elevated concentrations of ferrous iron, carbon dioxide, methane, and chloride were detected in the southeastern portion of the sampling line where TCE concentrations tended to be relatively low and VC concentrations were relatively high. The detected concentrations of these geochemical indicator parameters indicate that reductive dehalogenation of CAHs dissolved in groundwater is occurring in an anaerobic, reducing environment.

Samples were generally collected at approximately 25-foot intervals across the majority of the CAH plume (except at the golf course tee box, where the sampling interval was wider to avoid disruption of golf course activity); therefore, these results should be reasonably representative of concentrations migrating toward Leon Creek. Upstream from the dam it is likely that these concentrations are diluted as they near the creek due to the relatively flat hydraulic gradient and the potential for surface water recharge of the surficial aquifer. Temporary well LF014TW120 was located approximately 270 feet from Leon Creek in an area of relatively low well density (Figure 2.1). Detected concentrations of TCE, *cis*-1,2-DCE, and VC in groundwater from this well were 488 µg/L, 491 µg/L, and 18.2 µg/L, respectively. No concentrations approaching those detected in upgradient well LF014MW085 in 1998 (90,000 µg/L of TCE) were detected in the January 2000 samples. This observation suggests that this contamination has not yet migrated to the creek, the contamination is migrating to the creek along an as-yet-undetected pathway, or the earlier detection is erroneous.

### 3.3 CONTAMINANT MIGRATION

Groundwater surface elevations measured in January 2000 are summarized in Table 3.2. An updated water table map depicting inferred groundwater flow directions is shown on Figure 3.4. The configuration of the water table shown on this figure is similar to that derived by SAIC (1998) and shown on Figure 1.6. The hydraulic gradient near the creek upstream from the dam is relatively flat due to the elevated water level in the creek. The elevation of the water surface in the creek directly opposite temporary well LF014TW016 was surveyed during the January 2000 field program. This elevation, 622.52 feet above mean sea level (amsl), was only 0.06 foot lower than the groundwater surface elevation measured in TW016, indicating a hydraulic gradient of approximately 0.001 foot per foot (ft/ft) between the well and the creek. This relatively flat hydraulic gradient likely causes the contaminant discharge rate into the creek to be lower upstream from the dam than downstream where the gradient is steeper.

It should be noted that previous aquifer tests have indicated that the hydraulic conductivity of the gravelly alluvium overlying the Navarro Clay northwest of the dam is

**TABLE 3.2**  
**GROUNDWATER ELEVATIONS**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Well Identification	Top of Casing Elevation (ft amsl) <sup>b)</sup>	Depth to Water (ft btoc) <sup>c)</sup>	Water Table Elevation (ft amsl)	Product Thickness (feet)	Adjusted Watertable Elevation <sup>d)</sup> (ft amsl)
LF014TW102	632.62	12.60	620.02	N/A <sup>e)</sup>	N/A
LF014TW103	633.14	13.19	619.95	N/A	N/A
LF014TW104	632.99	12.53	620.46	N/A	N/A
LF014TW105	632.95	10.90	622.05	N/A	N/A
LF014TW106	632.66	10.37	622.29	N/A	N/A
LF014TW107	628.37	5.91	622.46	N/A	N/A
LF014TW108	629.06	6.58	622.48	N/A	N/A
LF014TW109	630.60	8.11	622.49	N/A	N/A
LF014TW110	630.24	7.70	622.54	N/A	N/A
LF014TW111	628.63	5.96	622.67	N/A	N/A
LF014TW112	628.10	5.45	622.65	N/A	N/A
LF014TW113	629.84	7.24	622.60	N/A	N/A
LF014TW114	631.65	9.06	622.59	N/A	N/A
LF014TW115	631.98	8.82	623.16	N/A	N/A
LF014TW116	630.38	7.80	622.58	N/A	N/A
LF014TW117	631.74	8.62	623.12	N/A	N/A
LF014TW118	631.84	8.71	623.13	N/A	N/A
LF014TW119	628.46	5.81	622.65	N/A	N/A
LF014PZ129	642.66	19.41	623.25	N/A	N/A
LF014PZ128	640.87	11.96	628.91	sheen	N/A
LF014TW120	642.98	14.27	628.71	N/A	N/A
LF014MW003	626.39	12.47	613.92	N/A	N/A
LF014MW005	627.75	5.16	622.59	N/A	N/A
LF014MW006	631.21	4.12	627.09	N/A	N/A
LF014MW007	630.74	7.41	623.33	N/A	N/A
LF014MW008	629.51	6.90	622.61	N/A	N/A
LF014MW009	636.39	9.96	626.43	N/A	N/A
LF014MW010	635.25	8.77	626.48	N/A	N/A
LF014MW011	630.37	10.35	620.02	N/A	N/A
LF014MW012	623.11	0.70	622.41	N/A	N/A
LF014MW015	634.35	5.44	628.91	N/A	N/A
LF014MW016	631.97	5.26	626.71	N/A	N/A
LF014MW017	630.78	7.64	623.14	N/A	N/A
LF014MW018	630.67	7.47	623.20	sheen	N/A
LF014MW020	631.23	4.65	626.58	sheen	N/A
LF014MW021	630.90	5.91	624.99	0.62	625.6
LF014MW022	628.62	6.14	622.48	N/A	N/A
LF014MW023	630.49	7.25	623.24	N/A	N/A
LF014MW025	626.29	3.88	622.41	N/A	N/A
LF014MW026	626.64	8.06	618.58	N/A	N/A
LF014MW028	633.50	9.70	623.80	N/A	N/A
LF014MW029	629.87	7.21	622.66	N/A	N/A
LF014MW075	629.82	7.13	622.69	N/A	N/A

**TABLE 3.2 (Continued)**  
**GROUNDWATER ELEVATIONS**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Well Identification	Top of Casing Elevation (ft amsl) <sup>b/</sup>	Depth to Water (ft btoc) <sup>c/</sup>	Water Table Elevation (ft amsl)	Product Thickness (feet)	Adjusted Watertable Elevation <sup>d/</sup> (ft amsl)
LF014MW076	637.21	2.63	634.58	N/A	N/A
LF014MW077	633.21	13.07	620.14	N/A	N/A
LF014MW078	632.47	11.45	621.02	N/A	N/A
LF014MW079	633.48	12.57	620.91	N/A	N/A
LF014MW080	631.96	11.74	620.22	N/A	N/A
LF014MW081	631.97	13.08	618.89	N/A	N/A
LF014MW082	635.18	12.63	622.55	N/A	N/A
LF014MW083	634.52	12.62	621.90	N/A	N/A
LF014MW085	639.20	9.99	629.21	N/A	N/A
LF014MW086	634.01	0.57	633.44	sheen	N/A
LF014MW087	625.39	2.79	622.60	N/A	N/A
LF014MW088	625.49	2.89	622.60	N/A	N/A
LF014MW089	625.48	2.89	622.59	N/A	N/A
LF014NW090	625.81	2.57	623.24	N/A	N/A
LF014NW091	625.79	3.30	622.49	N/A	N/A
LF014PW046	645.94	17.01	628.93	N/A	N/A
LF014RW032 PZ	626.09	4.47	621.62	N/A	N/A
LF014RW033 PZ	625.47	3.00	622.47	N/A	N/A
LF014RW034 PZ	629.21	6.48	622.73	N/A	N/A
LF014RW035 PZ	628.38	5.79	622.59	N/A	N/A
LF014RW036 PZ	628.20	5.65	622.55	N/A	N/A
LF014RW037 PZ	627.67	5.30	622.37	N/A	N/A
LF014RW038 PZ	627.79	5.26	622.53	N/A	N/A
LF014RW039 PZ	630.30	12.71	617.59	N/A	N/A
LF014RW040 PZ	629.73	9.71	620.02	N/A	N/A
LF014RW041 PZ	629.05	11.60	617.45	N/A	N/A
LF014RW042 PZ	629.84	11.51	618.33	N/A	N/A
LF014RW043 PZ	633.46	11.60	621.86	N/A	N/A
LF014RW044 PZ	633.28	12.47	620.81	N/A	N/A
LF014RW045 PZ	634.76	12.97	621.79	N/A	N/A

<sup>a/</sup> Water table adjusted by multiplying the product thickness by an assumed specific gravity of the product (0.92) then adding the result to the elevation of the measured watertable.

<sup>b/</sup> ft amsl = feet above mean sea level.

<sup>c/</sup> ft btoc = feet below top of casing.

<sup>d/</sup> N/A = not applicable (i.e. no product was detected in the well).

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**FIGURE 3.4**  
**GROUNDWATER SURFACE ELEVATIONS**  
**IN THE SURFICIAL AQUIFER**  
**JANUARY 2000**

Site LF014 Contaminant Plume  
 Remedial Process Optimization  
 Kelly AFB, Texas

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**PARSONS**  
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Denver, Colorado

potentially very high (up to 1,600 ft/day). Therefore, the groundwater velocity in the area near the creek northwest of the dam may be significant despite the presence of a low hydraulic gradient. For example, assuming a hydraulic conductivity of 1,600 ft/day, a hydraulic gradient of 0.001 ft/ft, and an assumed effective porosity of 0.25, the advective groundwater velocity would be approximately 6 ft/day. During relatively wet periods when the flow rate in the creek (and the surface water level) is high, it is likely that the creek recharges the adjacent alluvial aquifer, and groundwater adjacent to the creek flows away from the creek.

The hydraulic conductivities listed for Sites LF014 and LF015 by SAIC (1998) and derived from slug and pump tests were determined to be log-normally distributed with a geometric mean value of 24 ft/day. Darcy's law was used to preliminarily estimate the rate at which groundwater in the CAH plume area discharges from Site LF014 to Leon Creek. Darcy's law is shown by the following expression:

$$Q = KIA$$

- Where:
- Q = water discharge rate;
  - K = hydraulic conductivity of the aquifer;
  - I = hydraulic gradient across the vertical plane through which discharge is occurring; and
  - A = cross-sectional area of the vertical plane through which discharge is occurring.

For calculation purposes, an approximately 900-foot-wide area encompassing nearly all of the CAH plume was subdivided into four sub-areas, each having different spatial and/or hydraulic characteristics (Appendix C). Hydraulic gradient values used in the calculation ranged from 0.001 ft/ft upstream from the dam to 0.13 ft/ft near the downstream foot of the dam. The geometric mean hydraulic conductivity value of 24 ft/day was used for each sub-area. The calculated groundwater discharge rate through the 900-foot-long vertical plane was 0.094 cfs, or 10 percent of the 7-day, 2-year (7Q2) low-flow rate of 0.94 cfs designated for this segment of the creek. The calculated discharge rate is equal to 2 percent of the harmonic mean flow rate of 4.59 cfs designated for this segment of the creek. These calculations suggest that contaminants discharging to the creek are substantially diluted.

Uncertainties regarding the actual rate of groundwater discharge to the creek include the fact that the measured hydraulic conductivities of subsurface materials at the site range over more than 3 orders of magnitude. If higher hydraulic conductivity values, which are more representative of the most permeable gravel intervals, are used in the calculation instead of the geometric mean for all of the tested aquifer materials, then the calculated groundwater discharge rate would be substantially higher. In addition, Darcy's law is probably not entirely applicable to this situation because a percentage of the groundwater discharging to the creek likely flows under the creek and then vertically upward through the creek bed. This type of flow system is not correctly simulated by the simple Darcy's law calculation described in the preceding paragraph. More accurate assessments of the groundwater discharge rate could potentially be made using the numerical model constructed for the site and presented by SAIC (1998). This is a

potentially desirable exercise because, as described in Section 4, state regulations allow the effects of dilution and mixing to be accounted for when assessing the impact of contaminant discharge to surface water.

### 3.4 CONTAMINANT SOURCES

As described in Section 1, one of the objectives of this RPO analysis was to use site information to attempt to identify significant contaminant source areas in the landfill. In order to achieve this objective, the following information was plotted on the revised water table map (Figure 3.4):

- The most recently detected CAH (TCE + *cis*-1,2-DCE + VC) concentrations in groundwater using data collected from 1998 through 2000; and
- Magnetic anomalies potentially representative of buried drums that were identified during the RI (HNUS, 1992a).

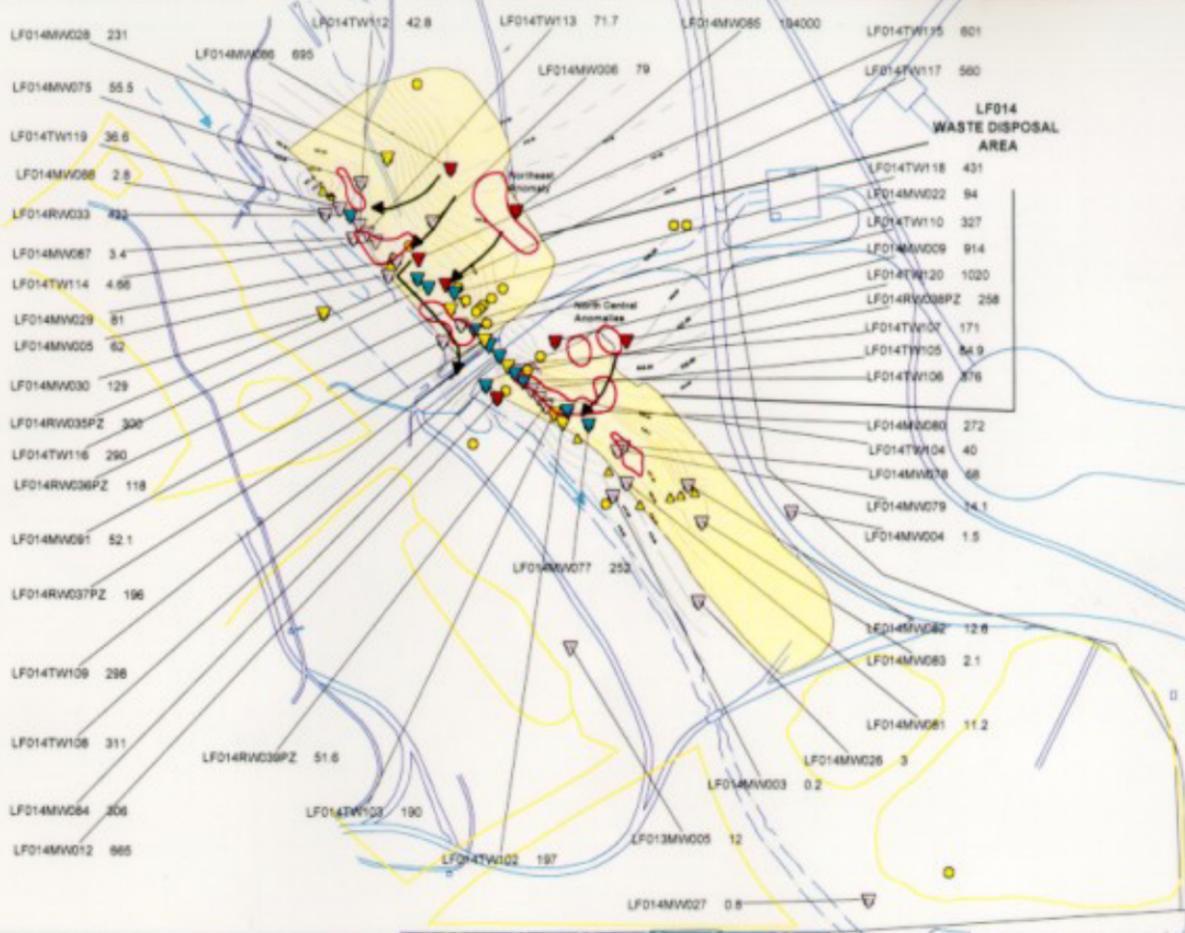
Well symbols on the resulting map (Figure 3.5) are color-coded to indicate whether the most recent total CAH concentration detected at the well is less than 100 µg/L, between 100 and 250 µg/L, between 250 and 500 µg/L, or greater than 500 µg/L.

The magnetometer survey performed during the RI by HNUS (1992a) measured the intensity of the magnetic field at each measurement location. The intensity of the magnetic field is elevated above the background intensity in areas where buried ferromagnetic materials are present. The areas of elevated magnetic field intensity are called anomalies, and indicate the possible presence of buried metal (e.g., drums). It is also possible for a disturbed area or a disposal area containing other (non-ferromagnetic) material to cause a magnetic anomaly if the backfill material has a different magnetic signature than the native materials. These anomalies are typically of lower magnitude (e.g., 25-50 gammas above or below background). The magnetic anomalies plotted are those containing total magnetic field readings that were more than 250 gammas above background. The most significant anomalies (containing readings greater than 1,000 gammas above background) are adjacent to well LF014MW085 (termed the “northeast” anomaly) and between wells LF014MW009 and LF014TW120 (termed the “north-central” anomaly). A map depicting all of the anomalies and their magnitudes is contained in Appendix G.

According to the RI report (HNUS, 1992a), the highest concentrations of VOCs detected in subsurface soil samples (TCE concentrations ranging from 1.8 to 6.8 mg/kg) were detected near the northeast anomaly. In addition, drums were visible at the ground surface in the vicinity of the north-central anomaly. TCE was detected during a soil vapor survey in the north-central anomaly area, and field analysis of a Navarro Clay sample from this area indicated the presence of TCE at a concentration of 25 mg/kg.

Available information suggests that the most elevated CAH concentrations detected in site groundwater (LF014MW085 and LF014MW015) may be sourced, at least in part, in the northeast magnetic anomaly area. Dissolved CAHs detected at LF014TW117 and LF014TW115 also may have originated from this potential source area, as these wells are potentially hydraulically downgradient from this area. The 1998 detection of TCE in groundwater from LF014MW085 at a concentration of 90,000 µg/L should be confirmed

FILE: \\E:\3\1045\MC\1045\KELLY\MAINT\CH\HSPACES\FIG3\LF014\CAHS.WRK DATE: 10/1/00 TIME: 10:00



**LEGEND**

Monitoring Well having detected concentration of chlorinated aliphatic hydrocarbons (CAHs) between 1998 and 2000. Value posted is most recent total CAH value (TCE + 1,2-DCE + VC) in µg/L

- ▲ Temporary Monitoring Well installed January 2000
- ▲ Recovery Well
- Monitoring Well
- Inferred Contaminant Migration Pathway
- Surface Water Flow Direction
- Line of Equal Groundwater Surface Elevation (feet above mean sea level; dashed where inferred)
- - - Magnetic Anomaly (>250 gammas above background) reported in HNU5 (1992a)

**Total CAHs**

- ▲ Greater than 500 µg/L
- ▼ 250 to 500 µg/L
- ▲ 100 to 250 µg/L
- ▼ Less than 100 µg/L

**FIGURE 3.6**

**DISTRIBUTION OF TOTAL CAHs RELATIVE TO INFERRED SOURCE AREAS**

Site LF014 Contaminant Plume Remedial Process Optimization  
Kelly AFB, Texas

**PARSONS**  
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Denver, Colorado

because it is substantially higher than any other CAH concentration detected in site groundwater. If this concentration is verified, the migration pathway for this contamination has not been defined.

Elevated CAH concentrations detected in wells LF014TW120, LF014MW080, LF014MW077, and LF014MW009 may be sourced, at least in part, in the north-central magnetic anomaly area, because these wells are either adjacent to or hydraulically downgradient from this area. Elevated CAH concentrations detected in three wells located immediately southeast of the dam (LF014MW084 and LF014MW012) may result from funneling of contaminated groundwater to this area from portions of the site to the north and northeast of this area. Such funneling may occur as a result of the relatively flat hydraulic gradient near the creek, which may cause groundwater to preferentially migrate to the southeast, parallel to the creek, through permeable gravel layers and eventually discharge to Leon Creek downstream from the dam.

Elevated CAH concentrations detected in the northeastern portion of the landfill at well LF014MW086 may be related to a small, lower-magnitude magnetic anomaly (Figure 3.5). Well LF014RW033, which also contains relatively elevated CAH concentrations, appears to be hydraulically downgradient from this anomaly area.

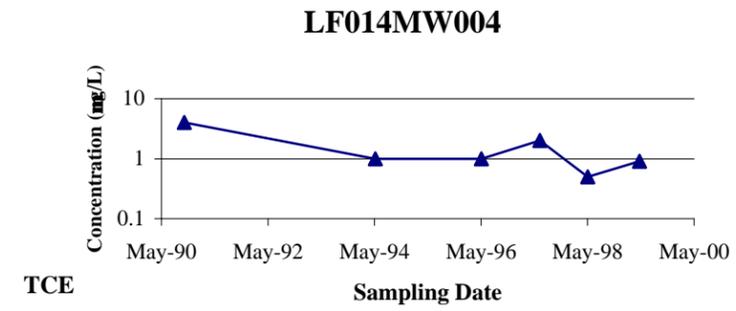
By far the highest lead concentration detected in site groundwater (16,500 µg/L) was detected at LF014MW078, in the southeastern portion of the site. Groundwater from this well also contained relatively elevated concentrations of cadmium (10 µg/L), total chromium (100 µg/L), iron (65,600 µg/L) mercury (1.5 µg/L), and selenium (70 µg/L). As shown on Figure 3.5, this well was installed at the location of a lower-magnitude magnetic anomaly that may indicate the presence of buried metallic wastes. Other wells that have contained elevated metal concentrations and which are located within or near magnetic anomalies (>250 gammas above background) include LF014RW033, LF014MW075, LF014MW085, LF014MW080, LF014MW077, and LF014MW079. Therefore, there may be some correlation between the results of the magnetic survey and the presence of metals in site groundwater.

### **3.5 TEMPORAL TRENDS IN CONTAMINANT CONCENTRATIONS**

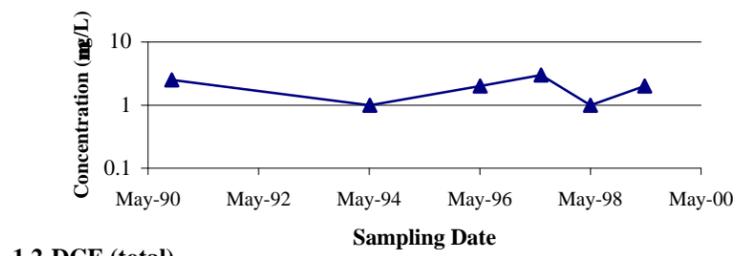
Concentrations of TCE, *cis*-1,2-DCE, and VC in selected wells with longer sampling histories were plotted against time (Figures 3.6a through 3.6c) to assess temporal trends. As shown on these figures, there do not appear to be significant increasing or decreasing concentration trends. The lack of trends suggests that the CAH sources have not substantially diminished over the observed time period due to the effects of natural attenuation, nor have new sources become activated (e.g., newly ruptured solvent containers).

With the exception of manganese, most of the elevated groundwater metal concentrations that have exceeded groundwater or surface water standards are associated with wells installed in 1998. Manganese concentrations have been relatively uniform over time, and generally appear to be representative of background concentrations. Substantially elevated metals concentrations have been detected over time in groundwater from well LF014MW003; however, this well is screened in the Navarro Clay and is therefore not representative of groundwater quality in the overlying surficial aquifer.

**FIGURE 3.6a**  
**TEMPORAL CONCENTRATIONS OF CAHS IN GROUNDWATER**  
 SITE LF014 CONTAMINANT PLUME  
 REMEDIAL PROCESS OPTIMIZATION  
 KELLY AFB, TEXAS



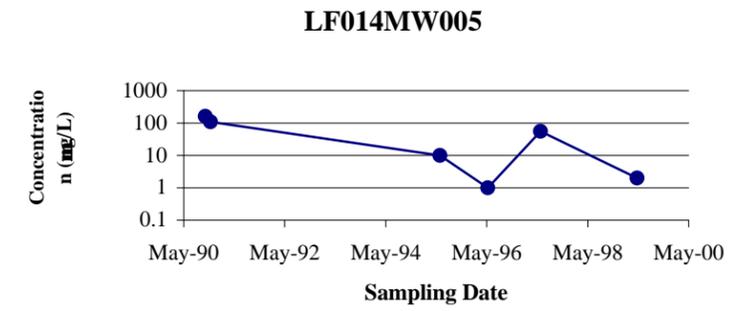
TCE



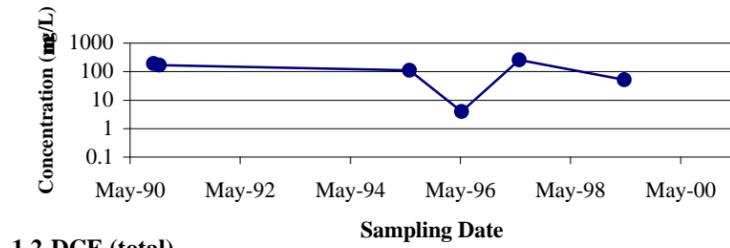
1,2-DCE (total)

Vinyl Chloride Concentrations for LF014MW004 are Below Detection Limits

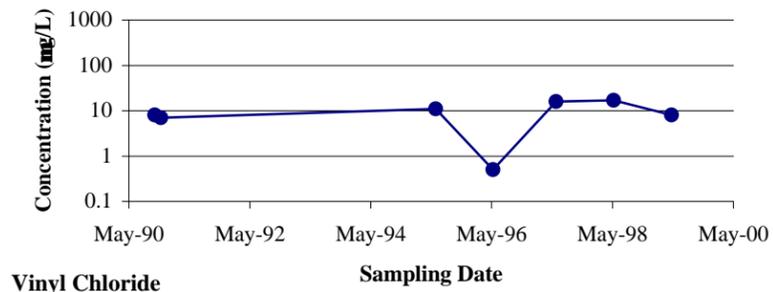
Vinyl Chloride



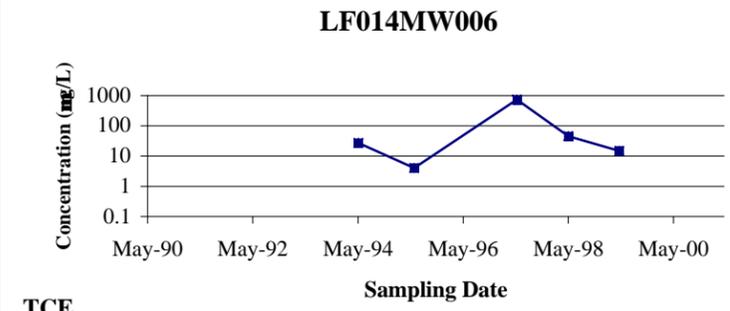
TCE



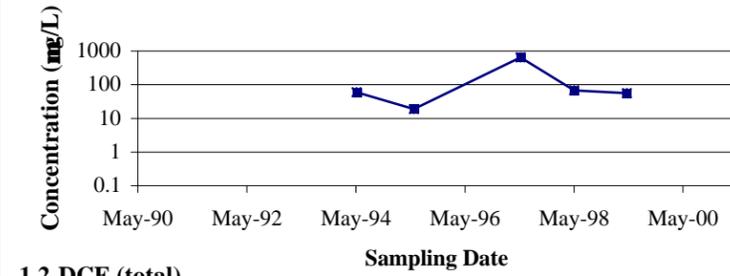
1,2-DCE (total)



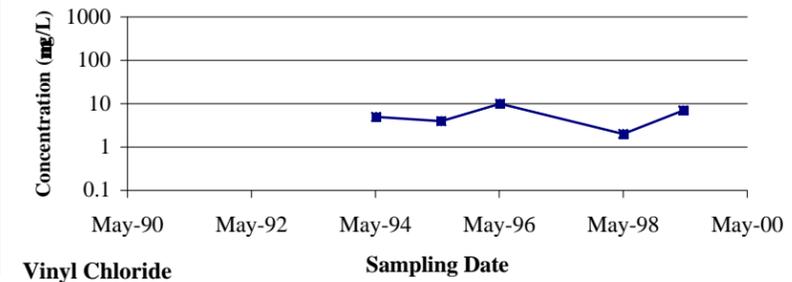
Vinyl Chloride



TCE

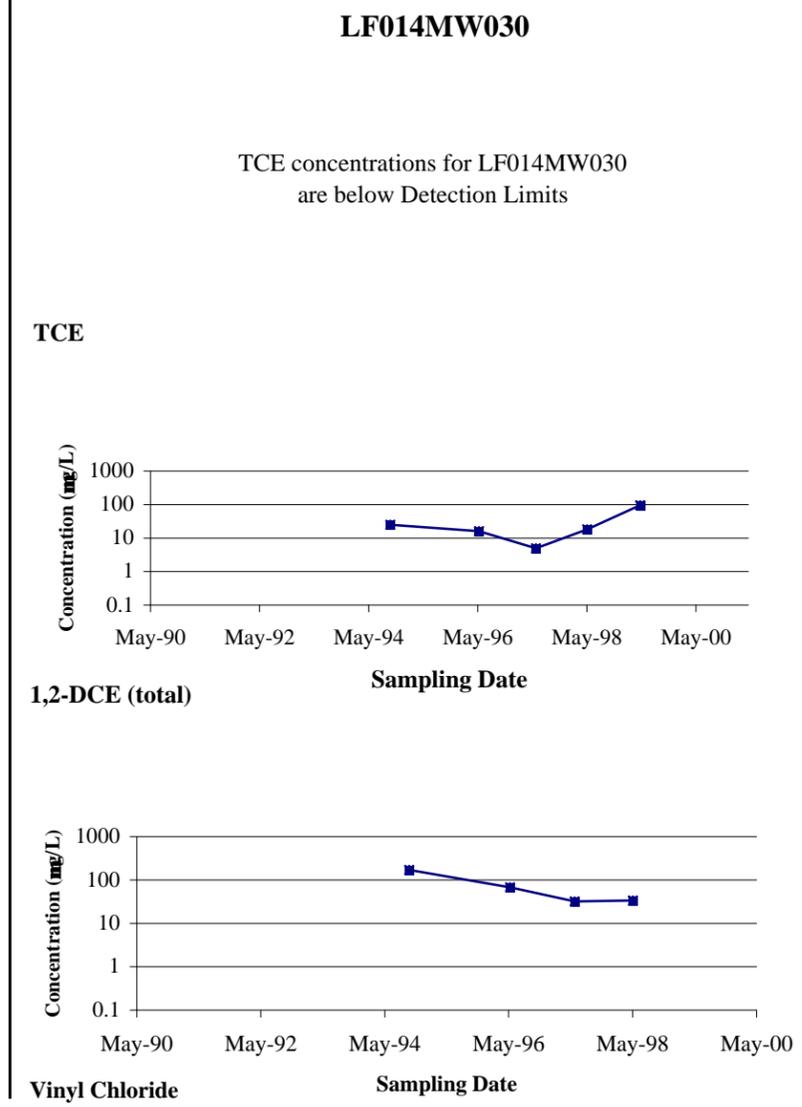
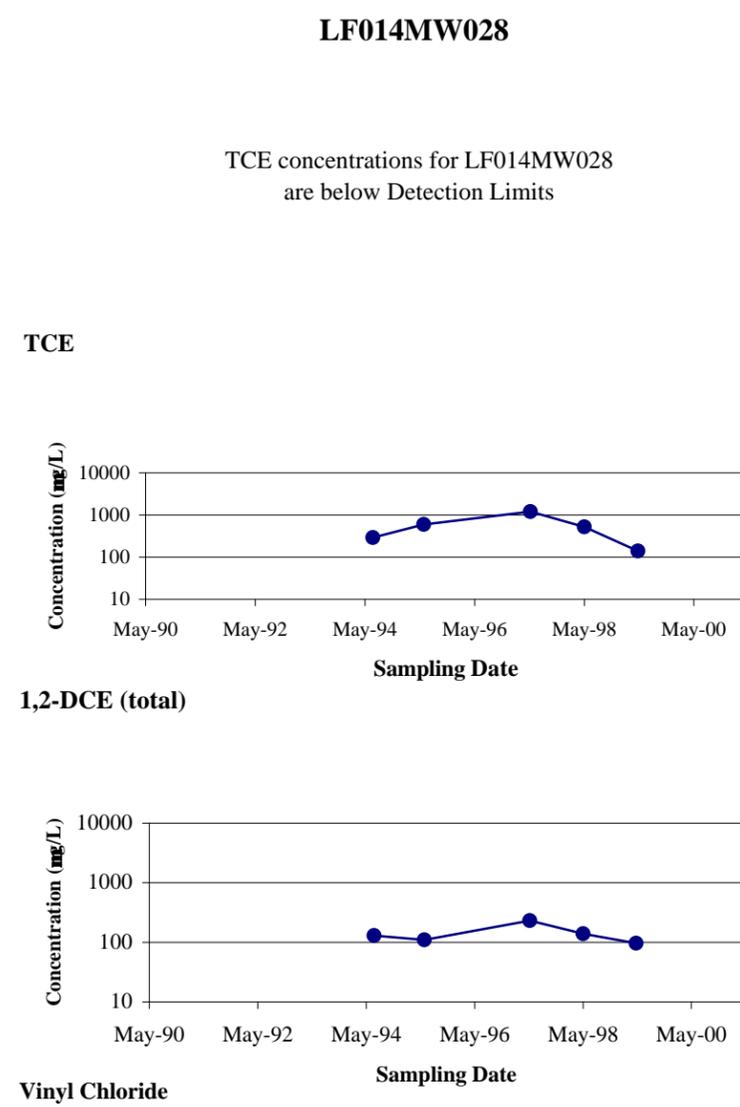
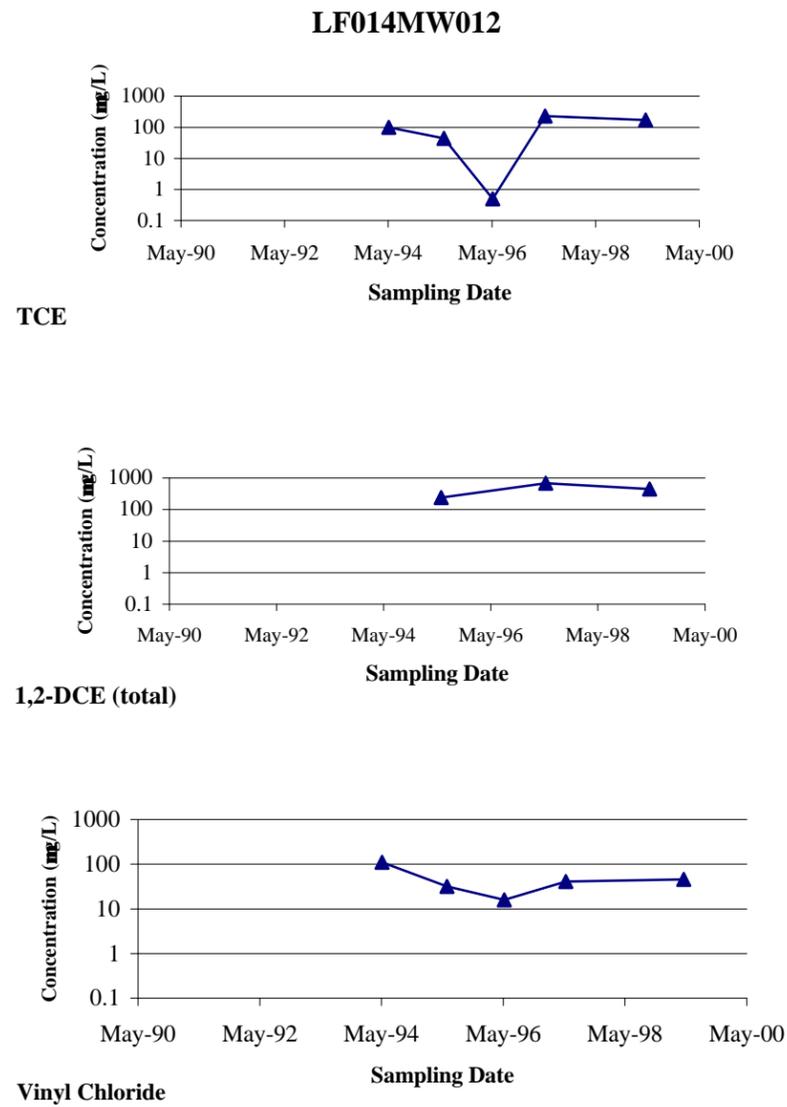


1,2-DCE (total)

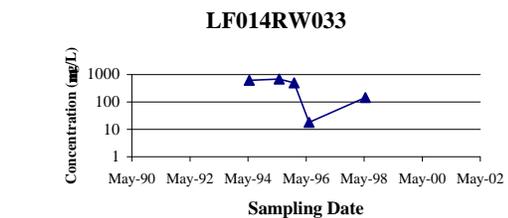


Vinyl Chloride

**FIGURE 3.6b**  
**TEMPORAL CONCENTRATIONS OF CAHS IN GROUNDWATER**  
 SITE LF014 CONTAMINANT PLUME  
 REMEDIAL PROCESS OPTIMIZATION  
 KELLY AFB, TEXAS



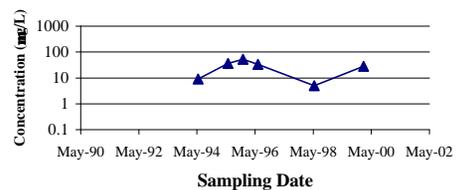
**FIGURE 3.6c**  
**TEMPORAL CONCENTRATIONS OF CAHS IN GROUNDWATER**  
 SITE LF014 CONTAMINANT PLUME  
 REMEDIAL PROCESS OPTIMIZATION  
 KELLY AFB, TEXAS



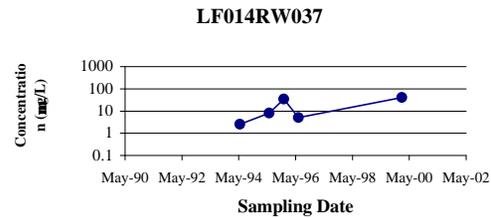
TCE

1,2-DCE (total) concentrations are not available for LF014RW033 for each sampling event

1,2-DCE (total)



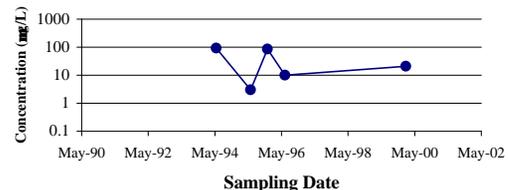
Vinyl Chloride



TCE

1,2-DCE (total) concentrations are not available for LF014RW037 for each sampling event

1,2-DCE (total)



Vinyl Chloride

Concentration histories for selected metals in “older” wells were examined to assess how metal concentrations in Site LF014 groundwater have varied over time. The metals selected for review were those that have been detected at least once at concentrations exceeding groundwater or surface water quality standards. However, in many cases these metals have not been present at detectable concentrations during the majority of sampling events, and no trends could be distinguished.

### **3.6 EVIDENCE OF CAH BIODEGRADATION VIA MICROBIALLY MEDIATED REDOX REACTIONS**

Biodegradation of dissolved CAHs and the future migration and persistence of these compounds are assessed in this section to support evaluation of the Site LF014 remedial system and the LTM plan. The discussion focuses on TCE, *cis*-1,2-DCE, and VC. As used here, the term “remediation by natural attenuation” (RNA) refers to a subsurface contaminant remediation strategy that relies on natural physical, chemical, and biological mechanisms to control exposure of potential receptors to concentrations of contaminants that exceed regulatory levels. These mechanisms include the processes of advection, hydrodynamic dispersion, dilution from recharge, sorption, volatilization, and biodegradation, which facilitate RNA of a variety of organic chemicals.

This section summarizes and interprets specific site characterization data relevant to documenting the effectiveness of RNA at minimizing dissolved CAH migration and reducing CAH concentration, mass, and toxicity over time. This assessment is used in the RPO evaluation to determine if natural attenuation may be a useful component in groundwater remediation at the site.

CAHs can be transformed, directly or indirectly, by biological processes. These compounds may undergo biodegradation through these three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated microbial process. A fourth degradation mechanism that may occur is abiotic degradation, including hydrolysis and dehydrohalogenation reactions. However, attributing degradation of CAHs to abiotic processes is usually difficult, particularly at the field scale (Butler and Barker, 1996).

At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be most likely. A more complete description of biodegradation reactions affecting CAHs is presented in the following subsections.

#### **3.6.1 Electron Acceptor Reactions (Reductive Dehalogenation)**

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. During this process, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. In general, reductive dehalogenation of chlorinated ethenes occurs by sequential dehalogenation from PCE to TCE to DCE to VC to ethene. Depending upon environmental conditions, this sequence may be interrupted, with other processes acting upon the products. During reductive dehalogenation, all three isomers of DCE can theoretically be produced; however,

Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated ethenes differently. The rate of reductive dehalogenation has been observed to decrease as the degree of chlorination decreases (Vogel and McCarty, 1985; Bouwer, 1994). PCE is the most susceptible to reductive dehalogenation because it is the most oxidized. Conversely, VC is the least susceptible to reductive dehalogenation because it is the least oxidized of these compounds. Murray and Richardson (1993) have postulated that this rate decrease may explain the accumulation of VC in some TCE plumes that are undergoing reductive dehalogenation.

In addition to being affected by the degree of chlorination of the CAH, reductive dehalogenation can also be controlled by the reduction/oxidation (redox) conditions of the site groundwater system. In general, reductive dehalogenation has been demonstrated under anaerobic nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994). Dehalogenation of PCE and TCE to DCE can proceed under mildly reducing conditions through nitrate reduction or ferric iron reduction (Vogel *et al.*, 1987), while the transformation of DCE to VC, or the transformation from VC to ethene requires more strongly reducing conditions (Freedman and Gossett, 1989; DeStefano *et al.*, 1991; DeBruin *et al.*, 1992).

Because CAHs are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur (Bouwer, 1994). Potential carbon sources can include low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter; fuel hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes (BTEX); landfill leachate; or substances intentionally introduced to promote reductive dehalogenation (e.g., vegetable oil).

### **3.6.2 Electron Donor Reactions**

Under aerobic conditions some CAHs can be utilized as the primary substrate (i.e., electron donor) in biologically mediated redox reactions (McCarty and Semprini, 1994). In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded CAH. In contrast to reactions in which the CAH is used as an electron acceptor, only the less-oxidized CAHs can be utilized as electron donors in biologically mediated redox reactions.

Davis and Carpenter (1990) and McCarty and Semprini (1994) describe the aerobic oxidation of VC in groundwater. In addition, Bradley and Chapelle (1996) show evidence of oxidation of VC under iron-reducing conditions so long as there is sufficient bioavailable iron (III). Klier *et al.* (1996) write that naturally occurring microorganisms in soil and groundwater are capable of biodegrading DCE by using this compound as a primary substrate (i.e. an electron donor). Murray and Richardson (1993) write that microorganisms are generally believed to be incapable of growth using TCE and PCE.

Aerobic oxidation of VC and DCE or reduction of VC under iron-reducing conditions may be characterized by contaminant mass loss, a decreasing molar ratio of DCE and/or VC to other CAH compounds, and the presence of elevated carbon dioxide concentrations.

Bradley *et al.* (1998) report that 1,2-DCE and VC can be anaerobically oxidized through the use of humic-acid compounds as electron acceptors. Therefore, naturally occurring humic-acid compounds can play a significant role in the degradation of these compounds under these conditions.

### 3.6.3 Cometabolism

When a CAH is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the CAH is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the CAH; rather, the cometabolic degradation of the CAH may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor (McCarty and Semprini, 1994).

Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation (Murray and Richardson, 1993; McCarty and Semprini, 1994; Vogel, 1994;). Vogel (1994) further elaborates that the cometabolism rate increases as the degree of dehalogenation decreases.

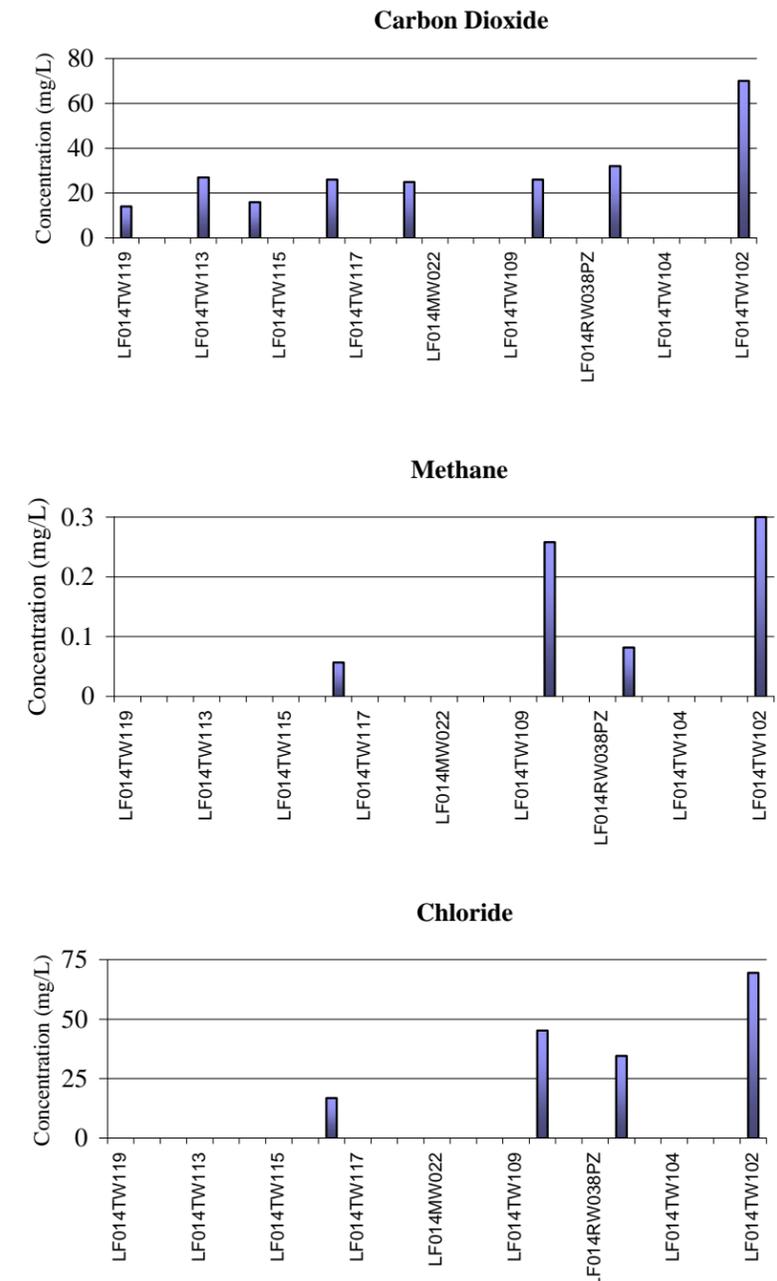
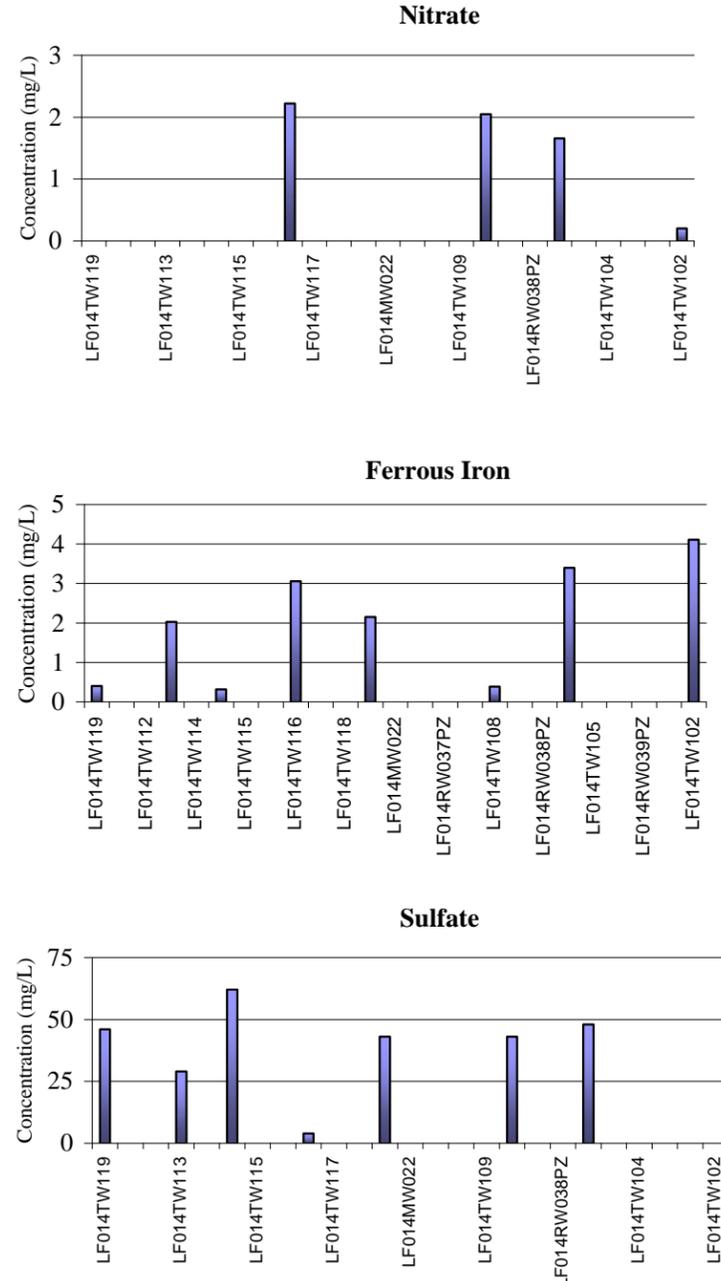
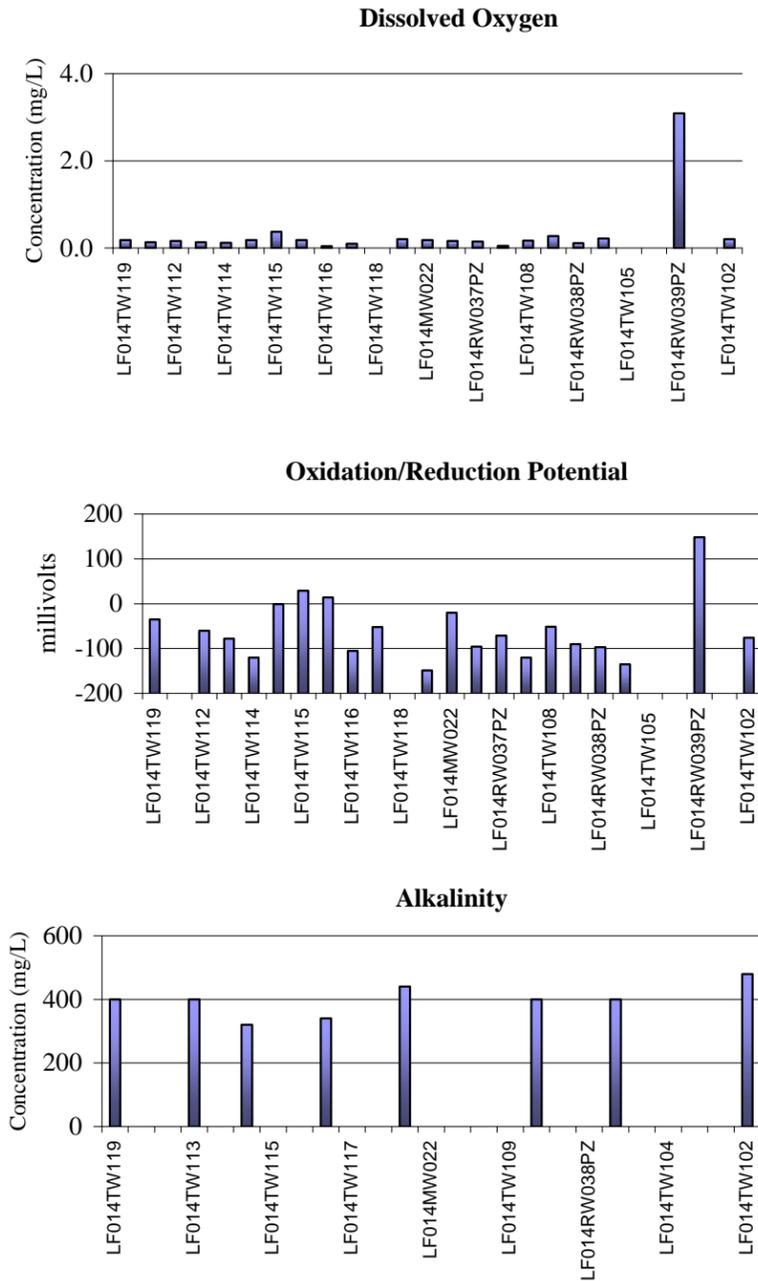
### 3.6.4 Summary of CAH Biodegradation at Site LF014

The abundance of reductive dehalogenation daughter products (i.e., *cis*-1,2-DCE and VC) in Site LF014 groundwater is a direct indication that significant biotransformation of TCE via reductive dehalogenation is occurring. As shown on Figure 3.2, concentrations of the reductive dehalogenation daughter product *cis*-1,2-DCE detected in January 2000 along a line parallel to and approximately 60 feet northeast of Leon Creek are frequently greater than concentrations of the parent compound (i.e., TCE). Although VC is being produced via the reductive dehalogenation of *cis*-1,2-DCE, the relative abundance of DCE and continued presence of TCE indicates that conditions are not sufficiently reducing at most locations to promote more rapid and complete transformation of TCE to DCE and DCE to VC. This observation is supported by the relative scarcity and low magnitude (typically less than 5 µg/L) of detected ethene concentrations.

Examination of historical CAH data for wells located throughout the CAH plume indicates that TCE is being reductively transformed throughout the plume, and not just near the downgradient (southwestern) edge of the landfill where samples were collected in January 2000. In fact, at some locations within the interior of the landfill (e.g., wells LF014MW009 and LF014MW028), VC is the dominant CAH, indicating that more complete transformation of TCE and DCE has occurred.

The groundwater geochemistry along the January 2000 sampling line is illustrated on Figure 3.7, and geochemical data are summarized in Table 3.3. As shown on Figure 3.7,

**FIGURE 3.7**  
**GEOCHEMISTRY OF GROUNDWATER ALONG SAMPLING LINE IN JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**



Note: Not all wells were sampled for all parameters (see Table 3.2).

**TABLE 3.3**  
**GROUNDWATER GEOCHEMICAL DATA - JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Sample Location	Methane (mg/L) <sup>c/</sup>	Ethane (mg/L)	Ethene (mg/L)	TOC <sup>a/</sup> (mg/L)	DOC <sup>b/</sup> (mg/L)	Nitrate +			Ferrous Hydrogen			Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Dissolved Oxygen (mg/L)	Redox Potential (mV) <sup>d/</sup>	pH (SU) <sup>e/</sup>	Temperature (°C) <sup>f/</sup>	Conductivity (µs/cm) <sup>g/</sup>
						Chloride (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Iron (mg/L)	Sulfide (mg/L)	Sulfate (mg/L)							
LF014TW102	0.3	0.002 U <sup>h/</sup>	0.003 U	4.01	NA <sup>i/</sup>	69.5	0.4 U	NA	4.11	NA	NA	480	70	0.20	-76	6.7	22.3	1,070
LF014TW103	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LF014TW104	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LF014TW105	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LF014TW106	0.0818	0.002 U	0.003 U	2.71	NA	34.6	1.66	NA	3.4	0	48	400	32	0.22	-135	6.4	18.5	829
LF014TW107	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.27	-90	7.1	18.3	802
LF014TW108	0.258	0.002 U	0.003 U	2.93	3.47	45.2	2.05	NA	0.39	0	43	400	26	0.17	-51	7.0	19.8	775
LF014TW109	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.05	-120	7.0	22.3	850
LF014TW110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.16	-96	6.9	21.8	790
LF014TW112	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.20	-60	7.0	18.6	691
LF014TW113	NA	NA	NA	NA	NA	NA	NA	NA	2.03	0	29	400	27	0.13	-78	7.0	18.8	667
LF014TW114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.12	-120	6.8	20.0	776
LF014TW115	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.37	29	7.1	20.9	633
LF014TW116	0.0566	0.002 U	0.003 U	3.7	NA	16.8	2.22	NA	3.06	0	4	340	26	0.04	-105	7.0	17.6	609
LF014TW117	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.10	-52	7.0	20.1	733
LF014TW118	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LF014TW119	NA	NA	NA	NA	NA	NA	NA	0.4	0.4	0	46	400	14	0.18	-35	NA	18.5	797
LF014TW120	0.001 U	0.002 U	0.003 U	1.61	NA	19.9	4.61	NA	0	0	30	320	15	0.25	517	NA	19.9	681
LF014RW033	NA	NA	NA	NA	2.46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LF014RW033 PZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.13	-65	NA	19.5	867
LF014RW035 PZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.18	14	NA	22.8	734
LF014RW036 PZ	NA	NA	NA	NA	NA	NA	NA	3	2.15	0.7	43	440	25	0.20	-149	NA	20.1	827
LF014RW037 PZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.15	-71	NA	26.9	991
LF014RW038 PZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.11	-97	6.8	42.9	1,230
LF014RW039 PZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.09	148	7.0	23.6	1,820
LF014MW022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.18	-20	NA	20.7	797
LF014MW029	NA	NA	NA	NA	NA	NA	NA	NA	0.32	0	62	320	16	0.18	-1	NA	19.50	704

**TABLE 3.3 (Continued)**  
**GROUNDWATER GEOCHEMICAL DATA - JANUARY 2000**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Sample Location	Methane (mg/L) <sup>c/</sup>	Ethane (mg/L)	Ethene (mg/L)	TOC <sup>a/</sup> (mg/L)	DOC <sup>b/</sup> (mg/L)	Nitrate +			Ferrous Hydrogen		Sulfate (mg/L)	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Dissolved Oxygen (mg/L)	Redox Potential (mV) <sup>d/</sup>	pH (SU) <sup>e/</sup>	Temperature (°C) <sup>f/</sup>	Conductivity (µs/cm) <sup>g/</sup>
						Chloride (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Iron (mg/L)	Sulfide (mg/L)								
LF014MW078	0.001 U	0.002 U	0.003 U	1.11	NA	12.8	4.98	0	0	0	76	320	16	2.34	82	NA	20.3	616
LF014MW082	0.001 U	0.002 U	0.003 U	1.58	NA	12.9	4.66	0	0	0	0	320	15	3.15	486	NA	22.5	646
LF014PW046	0.001 U	0.002 U	0.003 U	1 U	NA	13.4	5.04	0	0	0	20	280	15	3.8	587	NA	20.2	576
LF014MW076	0.001 U	0.002 U	0.003 U	1 U	NA	15.8	5.15	0	0	0	36	280	15	0.40	702	NA	21.9	719

<sup>a/</sup> TOC = Total organic carbon.

<sup>b/</sup> DOC = Dissolved organic carbon.

<sup>c/</sup> mg/L = milligrams per liter.

<sup>d/</sup> mV = millivolts.

<sup>e/</sup> SU = Standard units.

<sup>f/</sup> °C = degrees centigrade.

<sup>g/</sup> µs/cm = microsiemens per centimeter.

<sup>h/</sup> U = analyte not detected at the indicated detection limit.

<sup>i/</sup> NA = not analyzed.

the groundwater along the January 2000 sampling line is anaerobic and reducing. These conditions are conducive to the reductive dehalogenation of TCE and indicate the presence of a carbon source within the landfill. The overall lack of detected fuel hydrocarbons in site groundwater indicates that another form of carbon is acting as a food source for indigenous microbial populations, resulting in the depletion of DO. The relatively elevated DO concentration and oxidation-reduction potential (ORP) of groundwater at LF014RWR039PZ (the piezometer screened within the filter pack of RW039) is anomalous. Examination of historical DO and ORP data obtained throughout the landfill indicates that the groundwater at many locations is anaerobic and reducing.

The degree to which the landfill is creating conditions that are conducive to biodegradation of CAHs was assessed by comparing plume core geochemistry to background geochemistry (Table 3.4). Plume core wells used in this assessment include LF014TW102, TW106, TW108, and TW116. Wells interpreted to be more representative of background conditions include LF014MW082 (near the southeastern edge of the CAH plume), LF014PW046 (upgradient from the landfill), and LF014MW076 (upgradient from the CAH plume). In reality, wells LF014MW082 and LF014PW046 have had detectable concentrations of CAHs in the past; however, geochemical data from these wells suggest that they may be representative of background aquifer conditions.

The presence of anaerobic, reducing conditions within the landfill that are conducive to reductive dehalogenation of CAHs is supported by the following trends:

- Nitrate concentrations in groundwater from plume core wells are depleted relative to background conditions. After DO has been depleted in the microbiological treatment zone, nitrate may be used as an electron acceptor for anaerobic biodegradation of organic carbon via denitrification. Nitrate concentrations below background in areas with high organic carbon concentrations and low DO are indicative of the process of denitrification. However, if nitrate concentrations exceed 1 mg/L, then microorganisms may use nitrate instead of CAHs to produce energy (USEPA, 1998). Therefore, reductive dehalogenation of CAHs at Site LF014 may be inhibited in localized areas with higher nitrate concentrations.
- Concentrations of ferrous iron, methane, and chloride within the CAH plume are enhanced relative to background concentrations (Table 3.4). Ferrous iron and methane are produced in anaerobic, reducing environments, and methanogenic conditions are particularly conducive to the reductive dehalogenation of CAHs. Chloride is removed from CAHs during reductive dehalogenation and enters groundwater, causing chloride concentrations within the plume area to become elevated relative to background concentrations.
- Carbon dioxide concentrations and the alkalinity of groundwater within the CAH plume are enhanced. Carbon dioxide is produced during the biodegradation of organic carbon compounds. In aquifers that have carbonate minerals as part of the matrix, carbon dioxide forms carbonic acid, which dissolves these minerals, increasing the alkalinity of the groundwater.

**TABLE 3.4**  
**GEOCHEMICAL CONDITIONS IN BACKGROUND AND PLUME CORE**  
**GROUNDWATER**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Parameter <sup>a/</sup>	Units <sup>b/</sup>	Background Range	Background Average	Plume Range	Plume Average
DO	mg/L	0.40 to 3.80	2.45	0.04 to 0.22	0.16
ORP	mV	486 to 702	592	-51 to -135	-92
Nitrate + Nitrate (as N)	mg/L	4.66 to 5.15	4.95	0.40 to 2.22	1.58
Ferrous Iron	mg/L	Not detected	NA	0.39 to 4.11	2.74
Sulfate	mg/L	0 to 36	19	4 to 48	32
Methane	mg/L	0.001	0.001	0.06 to 0.30	0.17
TOC	mg/L	1.0 to 1.58	1.19	2.71 to 4.01	3.34
CO <sub>2</sub>	mg/L	15	15	26 to 70	38
Alkalinity	mg/L as CaCO <sub>3</sub>	280 to 320	293	340 to 480	405
Chloride	mg/L	12.9 to 15.8	14.0	16.8 to 69.5	41.5

a/ DO = dissolved oxygen; ORP = oxidation/reduction potential; N = nitrogen; TOC = total organic carbon; CO<sub>2</sub> = carbon dioxide.

b/ mg/L = milligrams per liter; mV = millivolts; CaCO<sub>3</sub> = calcium carbonate.

- The elevated TOC levels in groundwater from the CAH plume relative to background levels indicate that carbon source(s) are present within the landfill. Organic carbon acts as an energy source and drives reductive dehalogenation reactions.

Average plume core sulfate concentrations are anomalously high compared to background concentrations of this analyte, suggesting that sulfate-containing substances may have been disposed of in the landfill. USEPA (1998) notes that sulfate may compete with CAHs as an electron acceptor (sulfate may be preferentially used by microorganisms instead of CAHs) if sulfate concentrations exceed 20 mg/L. Therefore, reductive dehalogenation of CAHs at Site LF014 may be inhibited in localized areas with higher sulfate concentrations.

Given the predominance of anaerobic conditions within the CAH plume area, it is likely that aerobic biodegradation of CAHs is not a significant process. However, a localized, more-aerobic zone may exist adjacent to Leon Creek upstream from the dam during high-water periods when the surface water may recharge the aquifer. At these times, aerobic biodegradation of 1,2-DCE and especially VC may occur.

### 3.7 EXPOSURE PATHWAYS AND RECEPTORS

The surficial aquifer at Site LF014 is classified as a potential drinking water source. However, Kelly AFB has control over groundwater consumption within its boundaries, and currently there are no drinking water wells completed within the surficial aquifer on the Base. The FS (HNUS, 1996) states that “Zone 1 will continue to serve as a nonresidential area in the future. No permanent residences will be located in Zone 1, nor will this area be used for agricultural purposes; therefore, there will be no residential groundwater receptors within Zone 1.” Therefore, human receptors who may potentially be impacted by the Site LF014 contaminants include industrial workers who may excavate into and contact contaminated soils and groundwater. The exposure pathways for industrial workers include incidental ingestion of, or dermal contact with, contaminated soil and groundwater; or inhalation of volatilized contaminants or particulates/fugitive dust. In addition, recreational users (i.e., golfers) and groundskeepers could potentially be exposed to volatilized contaminants in the breathing zone. The CMS for soils (CH2M Hill, 1999d) concluded that potential risks to groundskeepers from soil ingestion, VOC and particulate inhalation, and dermal contact were within an acceptable range. Therefore, the potential for exposure of recreational users or groundskeepers to contaminated soils is low.

The significance of the groundwater-to-outdoor-air pathway was evaluated by comparing VOC concentrations detected in groundwater to residential and commercial/industrial inhalation standards issued by the TNRCC as part of the 1999 Texas Risk-Reduction Program (TRRP) (30 Texas Administrative Code [TAC] 350). Only two detections of VC have exceeded the residential inhalation standard of 380 µg/L for this compound (550 µg/L at LF014MW009 in 1995 and 1,400 µg/L at LF014MW085 in 1998). Only the 1998 detection of VC at LF014MW085 exceeded the commercial/industrial inhalation standard. All other detected VOC concentrations have not exceeded inhalation standards. This information indicates that groundwater contamination does not pose a significant outdoor air inhalation risk to human receptors.

According to CH2M Hill (1999a), the TNRCC has identified the following site-specific uses for the segment of Leon Creek that includes the reach adjacent to Site LF014: contact recreation, public water supply, and a high quality of aquatic life based on sensitivities of usual aquatic communities. Therefore, potential surface water receptors include aquatic life and recreational users (e.g., fisherman), and people who ingest the water as a drinking water source. Historically, a total of 14 analytes have been detected in site groundwater at concentrations exceeding chronic aquatic life standards, including 12 metals and 2 organic compounds. Twelve analytes have been detected in site groundwater at concentrations exceeding human-health-based surface water standards for ingestion of water and fish, including 7 metals and 5 organic compounds. Therefore, discharge of contaminated groundwater to Leon Creek is of potential concern. This issue is addressed in more detail in Section 4.

### 3.8 UPDATE OF CSM BASED ON REMEDIAL SYSTEM OPERATIONS

The following preliminary observations can be made based on the performance of the existing groundwater extraction system:

- Groundwater extraction rates for individual extraction wells confirm that the hydraulic characteristics of the surficial aquifer are spatially very variable, and suggest that non-uniform (preferential) migration of CAHs is occurring through more permeable zones; and
- The discontinuous nature of the permeable gravel zone makes plume capture with vertical wells impractical and ineffective.

## **SECTION 4**

### **EVALUATION OF REMEDIATION GOALS AND COCS**

A clear understanding of the goals and objectives of a remediation project is an essential step in the RPO process. An understanding of the original remediation goals is required to evaluate the merit of those goals in light of an evolving CSM and new regulatory approaches. This RPO evaluation provides an opportunity to review the RGs for Site LF014, and to promote additional interaction and communication with regulatory officials responsible for oversight of remediation activities. The objectives of this section are to:

- Summarize the regulatory framework presented in key documents that have previously been prepared for the site (e.g., RI/FS reports, risk assessments, and/or compliance plans);
- Review the RGs proposed in these key documents;
- Describe current regulatory options;
- Discuss the available options for determining COCs in Site LF014 groundwater;
- Summarize available RG options available under the current regulatory environment; and
- Discuss issues to be considered when selecting a regulatory option.

#### **4.1 KEY DECISION DOCUMENTS AND ASSOCIATED REMEDIATION GOALS**

##### **4.1.1 Remedial Investigation Report**

As discussed in Section 1.4.3, an RI of Zone 1 groundwater, including Site LF014, was performed by HNUS (1992a). The objectives of the RI were to characterize the nature and extent of contamination in soil and groundwater, and to assess human health risks associated with potential exposure to site-related contaminants. Given that a primary objective of this RPO report is to help guide the selection of future groundwater remedial actions at Site LF014, only human health risks associated with potential exposure to groundwater are summarized in this section. Potential future ingestion of onsite potable groundwater at Site LF014 by residents and onsite workers was evaluated in the RI (HNUS, 1992a). In addition, it was assumed in the RI that workers at Site LF014 may ingest groundwater from a leachate seep. Results of the risk assessment indicated the potential for adverse carcinogenic and noncarcinogenic health effects to future residents and workers that may ingest onsite potable groundwater (HNUS, 1992a).

Adverse health effects were not expected in workers who may ingest groundwater from the leachate seep.

#### **4.1.2 Feasibility Study**

Based on the results of the risk assessment (HNUS, 1992a) and an FFS (HNUS, 1992b), an interim remedial groundwater treatment system was installed at Site LF014 in 1993. A feasibility study for Zone 1 groundwater, including groundwater at Site LF014, was finalized in 1996 (HNUS, 1996). The FS was submitted to TNRCC for review, and Kelly AFB subsequently received a letter of approval from the state. The FS also was submitted for public review and comment. A Proposed Plan describing the alternatives for the groundwater OU containing Site LF014 was prepared and presented for public review. The public review and comment period began in July 1995 and concluded in August 1995. During a public meeting held in July 1995, the alternatives were presented to the public. The preferred alternative (OU1-14) recommended in the FS was agreed to by the TNRCC and involved the installation of additional monitoring wells, O&M of existing extraction wells, and O&M of treatment systems (treated groundwater is discharged to Leon Creek).

The FS for Zone 1 groundwater (HNUS, 1996) states that Kelly AFB intends to remediate Zone 1 groundwater under the TNRCC (1993) RRS 3 (30 TAC 335). RRS 3 requires a BRA for current and anticipated future land use conditions using site-specific data, which was completed in the RI (HNUS, 1992a). Per 30 TAC 335 (hereafter referred to as the Risk-Reduction Rules [RRRs]), site-specific cleanup levels (i.e., RGs) are back-calculated using the same exposure assumptions and algorithms that were used in the BRA. Kelly AFB has control over groundwater consumption within its boundaries, and currently there are no drinking water wells completed within the surficial aquifer on the Base. Although residential exposures are not expected for Zone 1 groundwater, the FS indicated that “Kelly AFB will use the residential exposure scenario for determination of risk-based cleanup levels” (HNUS, 1996). Therefore, the RGs listed in the FS for Zone 1 groundwater, which includes Site LF014 groundwater, are based on a residential exposure scenario. The hierarchy used in the FS to determine the RGs is summarized in Section 1.7.

Use of the residential exposure scenario for determination of risk-based cleanup levels is not consistent with current and reasonably expected future land use at Site LF014. Although the surficial aquifer at Site LF014 is classified as a potential drinking water source, Kelly AFB has control over groundwater consumption within its boundaries, and currently there are no drinking water wells completed within the surficial aquifer on the Base. The FS (HNUS, 1996) states that ‘Zone 1 will continue to serve as a nonresidential area in the future. No permanent residences will be located in Zone 1, nor will this area be used for agricultural purposes; therefore, there will be no residential groundwater receptors within Zone 1.’ Therefore, it is recommended that groundwater cleanup goals be based on non-residential industrial/recreator receptors who may be exposed to contaminants in LF014 groundwater or potentially impacted surface water.

#### **4.1.3 Compliance Plan**

In addition to RGs proposed in the Zone 1 groundwater FS (HNUS, 1996), corrective action objectives and GWP standards have been defined in TNRCC Compliance Plan No.

CP-50310, dated June 12, 1998. This Compliance Plan was issued in conjunction with RCRA Permit No. HW-50310. The Compliance Plan is specific to four RCRA-regulated units at Kelly AFB, which are not located in Zone 1. However, the Compliance Plan also applies to solid waste management units (SWMUs) located in Zones 1-5, including Site LF014. Allowable concentration limits in Zone 1 groundwater are specified in Table I of the Compliance Plan. These limits were developed in accordance with 30 TAC 335, and were based on one of the following:

- Medium-specific concentrations (MSCs) pursuant to 30 TAC 335.160;
- MCLs pursuant to 30 TAC 335.160 as specified in 40 Code of Federal Regulations (CFR) Part 141, National Primary Drinking Water Regulations Subparts B and G;
- Secondary maximum contaminant levels (SMCLs) pursuant to 30 TAC 335.160 as specified in 40 CFR Part 143, National Secondary Drinking Water Regulations;
- Practical Quantitation Limits (PQLs) as determined by the analytical methods of USEPA *SW-846 Test Methods for Evaluating Solid Waste*, Third Edition, November 1986, and as listed in the July 8, 1987 editions of the *Federal Register* and later editions; or
- Preliminary remediation goals (PRGs), which are health-based values proposed by Kelly AFB for those constituents that do not have MCLs, MSCs, or other state or federal standards.

## 4.2 REGULATORY OPTIONS

As noted in Section 4.1, current IRP documents for Zone 1 groundwater (i.e., the FS for Zone 1 groundwater [HNUS, 1996] and the TNRCC-approved June 12, 1998 Compliance Plan No. CP-50310) have relied on regulatory requirements specified in the Texas RRRs, (30 TAC 335) in determining remedial objectives and cleanup standards. However, the TNRCC (1999) has adopted a new rule, the Texas Risk-Reduction Program (TRRP) (30 TAC 350), which was published on September 17, 1999.

The TRRP rule outlines a comprehensive program that addresses the remediation of contaminated sites and the return of those sites to active and productive use. TRRP was developed with the following goals: 1) create a unified approach to corrective action that will be used to implement several different sets of corrective action regulations, such as the TNRCC Industrial and Hazardous Waste (including RCRA) and State Superfund Programs (current RRRs); 2) complete movement away from background as a cleanup standard; 3) implement a consistent, streamlined approach that will expedite remediations; and 4) answer a substantial number of technical, legal, risk assessment, and risk management policy questions that were not addressed in the previously promulgated risk-based rules. Generally, TRRP is applicable beginning May 1, 2000 unless the site meets exclusion or “grandfathering” conditions.

TNRCC recently released three draft regulatory guidance documents that are helpful in determining the applicability of TRRP: *An Introduction to the Texas Risk Reduction Program* (RG-366/TRRP-1); *TRRP Applicability and Grandfathering* (RG-366/TRRP-2); and *Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the*

*Shift* (RG-366/TRRP-4). These guidance documents are available on-line at [www.tnrcc.state.tx.us/permitting/trrp.htm](http://www.tnrcc.state.tx.us/permitting/trrp.htm); hardcopies are included in Appendix E. To determine if TRRP applies, three basic steps must be completed (RG-366/TRRP-2):

1. Determine if TRRP potentially applies: Does a permit, enforcement order, or rule other than TRRP require a response to a release or a closure of a waste management unit?
2. Determine if the site is excluded from TRRP.
3. Determine if the site is eligible to grandfather. If the site is not excluded, then it may still be able to remain under pre-TRRP requirements (grandfathering) if certain steps are taken. In some cases, these steps need to be taken before May 1, 2000.

A preliminary review of the exclusion criteria listed in RG-366/TRRP-2 suggests that Site LF014 could remain under the 1993 Texas RRR. For example, one of the exclusion criteria listed in the guidance document states that, "Facility closures are not required to comply with TRRP if an existing permit or order of the commission for that facility specifies the use of another rule or other performance criteria [30 TAC 350.2(h)(1)] ..." (TNRCC, 2000b). As discussed previously, the June 12, 1998 Compliance Plan No. CP-50310 was issued in conjunction with RCRA Permit No. HW-50310. In addition, a review of the grandfathering criteria suggests that Site LF014 may be remediated/closed under RRR Remedy Standard 3. The agency has been notified (as required by 30 TAC 335.8(c)) that Kelly AFB intends to proceed under the RRRs based on the assumption that Site LF014 qualifies for grandfathering. However, this does not preclude the Base from changing to TRRP at a later date (O'Brien, 2000).

The different options for determining COCs and remedial goals at Site LF014 are discussed in the following sections to facilitate a decision to proceed either under the 1993 Texas RRRs (30 TAC 335) or the more recent TRRP (30 TAC 350). In addition, points for consideration when selecting a regulatory option are discussed.

### **4.3 DETERMINATION OF COCS AND REMEDIAL GOALS**

COCs are defined as site contaminants that significantly contribute to the risk/hazard estimated for the specific receptors and exposure routes evaluated in the BRA. The processes for determining COCs under the 1993 RRRs versus the TRRP are different, as discussed in this section.

#### **4.3.1 Determination of COCs and RGs under the RRR**

As described in the 1993 RRRs, COCs under RRS 3 are identified as site-related chemicals with unacceptable risks/hazards (e.g., exceeding a risk level of 1E-06) based on the results of a BRA. Nineteen potential COCs were detected in Site LF014 groundwater during the RI (HNUS, 1992a). Results of the BRA (HNUS, 1992a) suggested that six of the detected chemicals (benzene, TCE, 1,2-DCE, VC, bis(2-ethylhexyl)phthalate, and manganese) potentially had unacceptable risks/hazards and were identified as final COCs. However, additional groundwater wells and a system of RWs have been installed and sampled at Site LF014 since the completion of the RI. As shown in Table 4.1, 60

**TABLE 4.1**  
**REGULATORY VALUES FOR GROUNDWATER AND SURFACE WATER**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Note: units = µg/L

<i>Detected Chemical</i>	<i>CAS</i>	<i>FS or RRR<sup>A/</sup></i>	<i>Compliance plan<sup>b/</sup></i>	<i>TRRP<sup>c/</sup></i>				<i>SW Quality Standards</i>		
				<i>Res-Ing</i>	<i>Res-Inh</i>	<i>Com/Ind-Ing</i>	<i>Com/Ind-Inh</i>	<i>AL_Chronic<sup>d/</sup></i>	<i>AL_Acute<sup>e/</sup></i>	<i>HH_SW_Fish<sup>f/</sup></i>
1,1,2-Trichloroethane	79005	3	5	5	8.00E+04	5	1.30E+05	NA <sup>e/</sup>	NA	NA
1,1-Dichloroethene	75354	7	7	7	2.30E+03	7	3.80E+03	NA	NA	7
1,2,4-Trichlorobenzene	120821	70	70	70	1.60E+07	70	2.20E+07	NA	NA	NA
1,2,4-Trimethylbenzene	95636	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	95501	600	600	600	5.80E+06	600	8.10E+06	NA	NA	NA
1,2-Dichloroethane	107062	5	5	5	3.30E+04	5	5.50E+04	NA	NA	5
1,3,5-Trimethylbenzene (Mesitylene)	108678	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	541731	600	600	730	9.20E+02	2200	1.30E+03	NA	NA	NA
1,4-Dichlorobenzene	106467	75	75	75	2.60E+07	75	3.70E+07	NA	NA	75
2-Chlorophenol	95578	180	183	120	6.20E+07	370	8.60E+07	NA	NA	NA
2-Methylnaphthalene	91576	NA	10	980	NA	2900	NA	NA	NA	NA
4-Methylphenol (P-Cresol)	106445	180	1830	120	1.20E+08	370	1.70E+08	NA	NA	NA
Acetone	67641	3650	3650	2400	2.50E+08	7300	3.50E+08	NA	NA	NA
Aluminum	7429905	NA	NA	24000	NA	73000	NA	NA	991 (d) <sup>b/</sup>	NA
Antimony	7440360	6	6	6	NA	6	NA	NA	NA	NA
Arsenic	7440382	50	50	50	NA	50	NA	190 (d)	360 (d)	50 (d)
Barium	7440393	2000	2000	2000	NA	2000	NA	NA	NA	2000 (d)
Benzene	71432	5	5	5	5.10E+04	5	8.50E+04	NA	NA	5
Benzyl Butyl Phthalate	85687	7300	5	4900	1.20E+08	15000	1.70E+08	NA	NA	NA
Beryllium	7440417	4	4	4	NA	4	NA	NA	NA	NA
Bis(2-Ethylhexyl) Phthalate	117817	6	6	6	NA	6	NA	NA	NA	NA
Cadmium	7440439	5	5	5	NA	5	NA	2.5 (d)	105 (d)	5 (d)
Carbon Disulfide	75150	3650	3650	2400	4.90E+06	7300	6.80E+06	NA	NA	NA
Chlorobenzene	108907	100	100	100	1.10E+06	100	1.50E+06	NA	NA	1305
Chromium, Total	5831/744	100	100	100	NA	100	NA	11 (d)	16 (d)	100
Cis-1,2-Dichloroethylene	156592	70	NA	70	1.60E+07	70	2.30E+07	NA	NA	NA
Cobalt	7440484	35000	940	1500	NA	4400	NA	NA	NA	NA
Copper	7440508	1300	1000	1300	NA	1300	NA	30 (d)	50 (d)	NA

**TABLE 4.1 (Continued)**  
**REGULATORY VALUES FOR GROUNDWATER AND SURFACE WATER**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Note: units = µg/L

<i>Detected Chemical</i>	<i>CAS</i>	<i>FS or RRR<sup>A/</sup></i>	<i>Compliance plan<sup>B/</sup></i>	<i>TRRP<sup>C/</sup></i>				<i>SW Quality Standards</i>		
				<i>Res-Ing</i>	<i>Res-Inh</i>	<i>Com/Ind-Ing</i>	<i>Com/Ind-Inh</i>	<i>AL_Chronic<sup>D/</sup></i>	<i>AL_Acute<sup>E/</sup></i>	<i>HH_SW_Fish<sup>F/</sup></i>
Cyanide	57125	200	200	200	NA	200	NA	10.69	45.78	200
Di-N-Butyl Phthalate	84742	3700	NA	2400	7.20E+07	7300	1.00E+08	NA	NA	NA
Di-N-Octylphthalate	117840	730	730	490	NA	1500	NA	NA	NA	NA
Dichlorodifluoromethane	75718	7300	NA	4900	3.00E+06	15000	4.20E+06	NA	NA	NA
Diethyl Phthalate	84662	29000	29200	20000	1.40E+08	58000	1.90E+08	NA	NA	NA
Dimethyl Phthalate	131113	NA	NA	20000	1.40E+08	58000	2.00E+08	NA	NA	NA
Ethylbenzene	100414	700	700	700	1.60E+07	700	2.20E+07	NA	NA	NA
Iron	7439896	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	7439921	15	15	15	NA	15	NA	13 (d)	296 (d)	5 (d)
Manganese	7439965	180	NA	1100	NA	10000	NA	NA	NA	NA
Mercury	7439976	2	2	2	7.30E+03	2	1.00E+04	1.3	2.4	0.0122
Methyl Ethyl Ketone (2-Butanone)	78933	22000	1830	15000	5.40E+08	44000	7.60E+08	NA	NA	4411
Methylene Chloride	75092	5	5	5	1.30E+06	5	2.10E+06	NA	NA	NA
N-Nitrosodiphenylamine	86306	NA	10	190	NA	420	NA	NA	NA	NA
N-Propylbenzene	103651	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	91203	150	1460	490	3.20E+05	1500	4.40E+05	NA	NA	NA
Nickel	7440020	100	100	490	NA	1500	NA	355 (d)	3336 (d)	NA
Nitrogen, Nitrate (As N)	14797558	10000	NA	10000	NA	10000	NA	NA	NA	NA
Pentachlorophenol	87865	1	1	1	1.30E+07	1	1.90E+07	15.03 (d)	2.25 (d)	129
Phosphorus, Total (As P)	7723140	NA	NA	0.49	NA	1.5	NA	NA	NA	NA
Selenium	7782492	50	50	50	NA	50	NA	5	20	50
Silver	7440224	180	183	120	NA	370	NA	NA	0.92	NA
Tetrachloroethylene(Pce)	127184	5	5	5	3.30E+05	5	5.50E+05	NA	NA	5
Thallium	7791120	0.5	2	2	NA	2	NA	NA	NA	NA
Tin	7440315	NA	NA	15000	NA	44000	NA	NA	NA	NA
Toluene	108883	1000	1000	1000	6.20E+06	1000	8.70E+06	NA	NA	NA
Trans-1,2-Dichloroethene	156605	100	NA	100	1.00E+07	100	1.40E+07	NA	NA	NA
Trichloroethylene (TCE)	79016	5	5	5	1.60E+05	5	2.70E+05	NA	NA	5

**TABLE 4.1 (Continued)**  
**REGULATORY VALUES FOR GROUNDWATER AND SURFACE WATER**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Note: units = µg/L

<i>Detected Chemical</i>	<i>CAS</i>	<i>FS or RRR<sup>A/</sup></i>	<i>Compliance plan<sup>b/</sup></i>	<i>TRRP<sup>c/</sup></i>				<i>SW Quality Standards</i>		
				<i>Res-Ing</i>	<i>Res-Inh</i>	<i>Com/Ind-Ing</i>	<i>Com/Ind-Inh</i>	<i>AL_Chronic<sup>d/</sup></i>	<i>AL_Acute<sup>e/</sup></i>	<i>HH_SW_Fish<sup>f/</sup></i>
Vanadium	7440622	260	110	170	NA	510	NA	NA	NA	NA
Vinyl Chloride	75014	2	2	2	3.80E+02	2	6.40E+02	NA	NA	2
Xylenes, Total	1330207	10000	10000	10000	7.30E+06	10000	1.00E+07	NA	NA	NA
Zinc	7440666	11000	5000	7300	NA	22000	NA	250 (d)	276 (d)	NA

<sup>A/</sup> FS or RRR = remediation goal (RG) identified in groundwater feasibility study (HNUS, 1992a) or, in cases where an RG was not identified, value was obtained from Appendix II of the 1993 Risk Reduction Rules (30 TAC 335).

<sup>b/</sup> Compliance Plan = RGs listed in Kelly AFB Compliance Plan (No. CP-50310).

<sup>c/</sup> Tier 1 values promulgated for the 1999 Texas Risk Reduction Program (TRRP) (30 TAC 350); Res-Ing = residential ingestion, Res-Inh = residential (outdoor) inhalation, Com/Ind-Ing = commercial/industrial ingestion, Com/Ind-Inh = commercial/industrial inhalation.

<sup>d/</sup> AL\_Chronic = freshwater chronic aquatic life standard from 30 TAC 307.6, Table 1.

<sup>e/</sup> Al\_Acute=freshwater acute aquatic life standard from 30 TAC 307.6, Table 1.

<sup>f/</sup> HH\_SW\_Fish = human health-based water and fish ingestion standard from 30 TAC 307.6, Table 3.

<sup>g/</sup> Not available

<sup>h/</sup> Standard based on dissolved concentration

chemicals (potential COCs) have been detected to date in Site LF014 groundwater. Given the significant number of additional compounds detected in Site LF014 groundwater since the RI, the final list of COCs cannot be determined under RRS 3 without a reassessment of potential risks/hazards associated with potential exposure to groundwater at Site LF014.

A comparison of maximum chemical concentrations detected in Site LF014 groundwater to RRS 2 residential drinking water values provides an indication of final COCs (i.e., the chemicals which may pose unacceptable risks/hazards under a drinking water scenario). Drinking water RGs listed in Appendix II of the 1993 RRRs (30 TAC 335) are shown in Table 4.1. For comparison purposes, drinking water RGs listed in the Zone 1 groundwater FS (HNUS, 1996), the Compliance Plan (No. CP-50310), and Table 3 (Tier 1 Groundwater protective concentration levels [PCLs]) of TRRP (30 TAC 350) also are provided in Table 4.1 for the 60 potential COCs detected in Site LF014 groundwater. Note also that 14 of the 60 detected compounds do not have drinking water RGs listed in the Compliance Plan (No. CP-50310), 10 do not have drinking water comparison values listed in the Zone 1 groundwater FS (HNUS, 1996) or Appendix II of the 1993 RRR (30 TAC 335), and 4 do not have drinking water comparison values listed in Table 3 of TRRP (30 TAC 350). The 1993 RRRs (30 TAC 335) require use of current USEPA toxicity information when assessing risk/hazard. A review of available drinking water values listed in Table 4.1 and in other USEPA sources (e.g., USEPA Region 9 [1999] PRG table) suggests that toxicity information is available for nearly all of the 60 chemicals detected in Site LF014 groundwater. Therefore, the RI BRA (HNUS, 1992a) would need to be revised to address all of the 60 detected chemicals in order to effectively determine the final list of COCs under a drinking water scenario using the RRRs (RRS 3). Note also that for a number of chemicals, the limits set forth in the Compliance Plan (No. CP-50310) differ from values listed in the FS (HNUS, 1996) and/or Appendix II of the 1993 RRRs (30 TAC 335). The reasons for these differences were not determined, but may be due to factors such as a change in a chemical's toxicity value, issues related to analytical detection limits, and/or exposure pathways incorporated into the derivation of cleanup goals.

Assuming that Site LF014 groundwater will be used as a future drinking water source, a preliminary review of maximum detected concentrations and the drinking water RGs in Table 4.1 suggests that approximately 50 percent of the 60 chemicals detected in Site LF014 groundwater (primarily VOCs and metals) could become final COCs. However, a preliminary assessment of chemical concentrations and the frequency of detections above drinking water levels suggests that the list of final COCs may be reduced significantly if: 1) site-to-background comparisons are performed; and 2) statistical comparisons between site concentrations and preliminary cleanup levels are conducted per USEPA (1989 and 1992) guidance and consistent with 30 TAC 335.553(d)(3).

As discussed above, the RGs proposed to date are based on the assumption that all groundwater beneath and downgradient from Site LF014 represents a potential drinking water source. However, COCs and their associated RGs in groundwater may be modified if it is documented to the agency's satisfaction that a future land use other than residential is appropriate for the site, and institutional or legal controls will effectively prevent use of contaminated groundwater (30 TAC 335.563(h)). Under this option, current and reasonably expected future exposure routes would need to be considered in the RRR

Standard 3 BRA, and alternate concentration limits would need to be calculated per 30 TAC 335.160(b).

The potential impact of deriving alternate concentration limits on the determination of final COCs is presented for an example chemical, TCE. Alternate concentration limits for TCE were derived based on non-drinking water exposure pathways, and are shown in Table 4.2. The risk-based alternate concentration limits were derived for an intrusive industrial worker (e.g., construction worker) and a child recreator (e.g., 5- to 10-year old that potentially swims in Leon Creek) based on the following assumptions:

- A target risk level of 1E-06 and target hazard quotient of 1;
- A construction worker contacts groundwater 30 minutes per day for 50 days (e.g., 10-week project, working 5 days per week) per year as a result of intrusive activities (e.g., excavation and installation of a utility line);
- Dermal contact with groundwater is the only complete and significant exposure pathway for the construction worker;
- The hands, forearms, and lower legs of the construction worker are the body parts dermally exposed;
- A child recreator potentially swims in Leon Creek two times per month (i.e., 24 days/year) for 60 minutes per event;
- Dermal contact and incidental ingestion (0.05 liters per event) while swimming are the only complete and significant surface water exposure pathways for the child recreator; and
- 100-percent of the child recreator’s body surface area is dermally exposed.

Details of the exposure assumptions, models, and input parameters used are presented in Appendix A.

**TABLE 4.2**  
**RISK-BASED ALTERNATE CONCENTRATION LIMITS**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Contaminant	Risk-Based Alternate Concentration Limit (µg/L)		Risk-Reduction Rule Drinking Water Standard (µg/L)
	Construction Worker	Child Recreator (swimmer)	
Trichloroethene	26,600	1,160	5

The alternate concentration limits presented in Table 4.2 are example calculations, and regulatory concurrence on land use and exposure assumptions would need to be obtained.

The determination of final COCs under Standard 3 of the RRR also involves an evaluation of the potential impact of groundwater discharge to Leon Creek. Leon Creek

is classified by the TNRCC as Upper Leon Creek (segment 1907) and Lower Leon Creek (segment 1906). Segment 1906 begins 100 meters upstream from State Highway 16 northwest of San Antonio and flows southward to its confluence with the Medina River, with about 2 miles of this segment within the southwestern portion of Kelly AFB. TNRCC has identified the following site-specific uses for Segment 1906 of Leon Creek: contact recreation, public water supply, and a high quality of aquatic life based on sensitivities of usual aquatic communities. As stated in 30 TAC 335.563(g), “Any discharge or release into or adjacent to surface water . . . occurring during or after attainment of Risk Reduction Standard No. 3, shall be compliant with the Texas Surface Water Quality Standards of Chapter 307.” Chemical concentrations in the groundwater-to-surface-water discharge zone must comply with the Texas Surface Water Quality Standards (30 TAC 335.563(h)(2)(C)(3)).

Although a BRA associated with potential exposure to surface water has not been conducted on the 60 chemicals detected in Site LF014 groundwater, a comparison of maximum groundwater concentrations (within the discharge zone) with surface water quality criteria (Tables 1 and 3 of 30 TAC 307.6) provides an indication of the chemicals that may be final COCs based on surface water exposure pathways. As shown in Table 4.1, TNRCC surface water quality standards are not available for the majority of the 60 chemicals detected in Site LF014 groundwater. The procedures for deriving aquatic (30 TAC 307.6(c)(7)) or human health criteria (30 TAC 307.6(d)(8)) when surface water quality criteria are not listed are described in the Surface Water Quality Standards rule. Risk-based drinking water values (e.g., MCLs) should be used for those chemicals without surface water quality standards (30 TAC 335.563(g)). Given the number of chemicals detected in Site LF014 groundwater that do not have surface water quality standards (Table 4.1), it will be necessary to compare groundwater concentrations with drinking water RGs or surface water quality criteria derived per 30 TAC 307.6 before finalizing the list of COCs.

In addition to the requirement that any discharge to surface water comply with the Texas Surface Water Quality Standards of Chapter 307, the discharge may be subject to the permitting requirements of Chapter 335 (30 TAC 335.563(g)). Given the likelihood that contaminants present in groundwater are diluted upon entering Leon Creek, the Base potentially could request authorization from the TNRCC to account for dilution when determining final surface water COCs and the need for remediation. This likely would require modification of an existing permit and/or requesting an additional discharge permit.

Metals present in groundwater near Leon Creek at concentrations exceeding surface water standards include total chromium, selenium, lead, cadmium, silver, nickel, zinc, mercury, and barium (Table 4.3). The groundwater samples analyzed for metals do not appear to have been field-filtered; therefore, it is likely that the detected concentrations represent total metal concentrations. Conversely, all of the chronic aquatic life standards and most of the water and fish ingestion standards are based on dissolved concentrations, which are generally lower than total concentrations. Therefore, direct comparison of metals concentrations in groundwater to surface water standards is not appropriate. In addition, groundwater samples have been analyzed for total chromium, whereas the chronic aquatic life standard of 11 µg/L is for hexavalent chromium (Table 4.3). The hardness-based standard for trivalent chromium, which is generally more prevalent in the environment, is 455 µg/L (assuming a site-specific average hardness value of

**TABLE 4.3**  
**METAL CONCENTRATIONS IN GROUNDWATER THAT EXCEED SURFACE**  
**WATER STANDARDS**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

Parameter	Sampling Date	Number of Wells at Which Standard Was Exceeded	Maximum Concentration in Groundwater (µg/L) <sup>a/</sup>	Chronic Aquatic Life Standard (µg/L) <sup>b/</sup>	Water and Fish Ingestion Standard (µg/L) <sup>a/</sup>
Chromium	1998	16	160	11	100
Selenium	1998	10	150	5	50
Lead	1996-1998	11	16,500	11.52	5
Cadmium	1995-1998	8	90	2.5	5
Silver	1997-1998	4	2.8	0.92 <sup>c/</sup>	NA <sup>d/</sup>
Nickel	1998	1	440	371	NA
Zinc	1995	1	309	250	NA
Mercury	1997-1998	9	1.5	1.3	0.0122
Barium	1998	1	2,050	NA	2000

<sup>a/</sup> µg/L = micrograms per liter.

<sup>b/</sup> Taken from 30 TAC 307.6, Tables 1 and 3.

<sup>c/</sup> Chronic standard not available; value presented is acute standard.

<sup>d/</sup> NA = not available.

261.48 mg/L, [CH2M Hill, 1999a]). Future analyses for chromium should speciate between these two forms of chromium to determine the most applicable standard and the true magnitude of the chromium “problem.” At least one round of dissolved (field-filtered) metal samples also should be collected to allow direct comparison of groundwater quality data to surface water standards.

As an example of the potential impact on the determination of final COCs, the TNRCC TEXTOX model was run to preliminarily assess the effects of dilution on metal concentrations. This model is used by the agency to assess if contaminant concentrations in effluent entering a surface water body from an outfall will exceed surface water standards after mixing with the surface water. Model input parameters and results are provided in Appendix D. TEXTOX uses the total suspended solids (TSS) concentration to estimate the percentage of the total contaminant concentration entering the surface water that will be dissolved in the water as opposed to adsorbed to suspended sediment particles. Stream-specific data for segment 1906 of Leon Creek were used, including TSS, hardness, pH, and chloride concentrations of 6 mg/L, 223 mg/L, 7.3 standard units, and 58 mg/L, respectively. The published 7-day, 2-year (7Q2) low flow and harmonic mean flow rates of 0.93 cfs and 4.59 cfs, respectively for this segment of Leon Creek also were used.

As described in Section 3.3, the average rate at which contaminated groundwater in the CAH plume area discharges to Leon Creek was preliminarily estimated at 0.094 cfs using Darcy’s law. Using a slightly higher discharge rate (0.15 cfs) and the creek-specific values listed in the preceding paragraph as input, the TEXTOX model indicates that

chromium, selenium, and lead are the only metals in groundwater that could potentially cause an exceedance of surface water quality standards due to discharge of Site LF014 groundwater (see Appendix X for results). These results suggest that the final list of metals COCs based on groundwater discharge to surface water at Site LF014 may be reduced significantly if TNRCC allows for dilution of groundwater contaminants upon entering Leon Creek. In addition to dilution, VOC concentrations in the creek will be further reduced by volatilization.

#### **4.3.2 Determination of COCs and RGs under TRRP**

If it is determined that TRRP (30 TAC 350) will be applied at Site LF014, the following general process must be followed:

1. A property assessment must be performed, which includes groundwater classification, land use determination, and adjacent landowner notification (if necessary);
2. Critical PCLs must be determined for the appropriate environmental media;
3. A response action capable of attaining the response objectives under Remedy Standard A or B must be developed;
4. Required reports must be developed and submitted to the agency; and
5. The response plan must be implemented.

TRRP lays out procedures for calculating RGs that are protective of human health and the environment (i.e., PCLs). Tier 1, 2, or 3 PCLs can be calculated under TRRP. Tier 1 is the simplest and least costly method to establish PCLs, but generally results in the most stringent levels. Tier 3 uses the most sophisticated methods and is likely the most expensive, but it factors in important site-specific considerations. Site-related chemicals detected at concentrations higher than their respective PCLs must be cleaned up or controlled under one of the two remedy standards (30 TAC 350.71-350.79).

Remedy Standard A is a cleanup option and may be “self-implemented” without prior approval from the TNRCC. However, a Self Implementation Notice must be submitted to the agency 10 calendar days before initiating cleanup. Remedy Standard B provides the option to control and manage COCs instead of cleaning them up. Under Remedy Standard B, the COCs must be controlled and managed to prevent unauthorized migration and exposures at levels above PCLs. Under Remedy Standard B, LTM likely will be required, financial assurance may be required, and institutional controls (deed notices and restrictive covenants) typically must be filed in county deed records. Remedy Standard B cannot be self-implemented, and a Response Action Plan must be submitted to and approved by TNRCC before implementation.

A BRA is not required to determine the final list of COCs under any tier of TRRP. Rather, PCLs are back-calculated by determining what concentrations could remain at the source and still yield protective concentrations at the point of exposure. TRRP defines mandatory exposure pathways that must be included in calculating PCLs for each of the land use classifications (e.g., residential or industrial). Final COCs under TRRP are those chemicals that exceed the critical PCLs. Tier 1 PCLs for the 60 chemicals detected in Site LF014 groundwater are listed in Table 4.1. A preliminary comparison of maximum

chemical concentrations detected in groundwater with Tier 1 residential and industrial drinking water PCLs suggests that approximately 50 percent of the 60 chemicals would be final COCs. The final COC list based on drinking water exposure under Tier 1 of TRRP (30 TAC 350) does not appear to differ significantly from the final COC list under the Texas 1993 RRR. In addition, the list of final COCs under a drinking water scenario does not differ significantly between residential and commercial land uses. However, as noted in 30 TAC 350.52, COCs with concentrations greater than the PCL may be left in place under a Remedy Standard B plume-management-zone approach (i.e., an exposure-prevention approach).

As with the RRRs, potential groundwater discharges to surface water must comply with the Surface Water Quality Standards rule (30 TAC 307) under TRRP. PCLs for chemicals in groundwater that discharge to surface water are calculated per an equation provided in TAC 350.75(b)(1), which includes a dilution factor term. As described in 30 TAC 350.75(i)(4), the dilution factor may be determined by measuring and/or estimating groundwater dilution in surface water from appropriate models of groundwater plume dispersion, tracer studies, receiving water and sediment sample analyses, analytical calculations, or other techniques upon the executive director's approval using site-specific base flow conditions for groundwater, 7Q2 conditions for receiving streams, and critical mixing conditions. Therefore, it appears that TRRP provides more specific guidance than the RRRs on groundwater-to-surface-water dilution when determining the final list of COCs for surface water protection. The potential impact of contaminant dilution upon entering Leon Creek on the determination of final COCs and RGs would be similar to that discussed for the RRRs (Section 4.3.1).

#### **4.4 POINTS TO CONSIDER IN SELECTING A REGULATORY OPTION**

The recent guidance document, *Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the Shift* (RG-366/TRRP-4), provides a comparison of important differences between RRR and TRRP that should be considered when selecting the regulatory option for assessment and potential remediation of contaminants at Site LF014. A select number of benefits and drawbacks associated with proceeding under RRR or TRRP are provided in Table 4.4.

**TABLE 4.4**  
**ISSUES TO CONSIDER IN SELECTING A REGULATORY OPTION**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

1993 Texas Risk-Reduction Rule (RRR)		1999 Texas Risk-Reduction Program (TRRP)	
Advantage	Disadvantage	Advantage	Disadvantage
Site LF014 may qualify for an exclusion or “grandfathering” from TRRP	A baseline risk assessment (BRA) must be conducted under Standard 3. Given the number of chemicals detected since the completion of the 1992 RI, the BRA may need to be revised.	A human health BRA is not required under any of the tiers.	
Alternate concentration limits may be derived for exposure pathways (e.g., dermal contact) other than ingestion of groundwater. Therefore, cleanup to drinking water standards may not be required, assuming exposure can be controlled through institutional or legal controls.	If it is assumed that Site LF014 groundwater is used as drinking water, cleanup levels need to be achieved throughout the plume.	It may not be necessary to perform all three tiers of the ecological risk assessment.	An ecological risk assessment is required. The rule defines a three-tiered approach for evaluating risk to ecological receptors.
Given the likelihood that contaminants present in groundwater are diluted upon entering Leon Creek, authorization from the TNRCC to account for dilution when determining final surface water COCs may be possible.	Groundwater will need to be remediated to the lower of the surface water quality and drinking water standards at the groundwater-to-surface water discharge zone (assuming no dilution of contaminants discharged to Leon Creek).	Remedy Standard B provides the option to control and manage COCs without active remediation through the use of a plume-management zone (i.e., an exposure-prevention approach).	Only two land-use options (residential and commercial/industrial) can be used in the derivation of human health PCLs. A detailed process (including possible public notification) is required for changing default commercial/ industrial exposure frequencies, durations, and averaging times.
The final list of COCs based on groundwater discharge to surface water may be reduced significantly if the TNRCC allows consideration of dilution of groundwater contaminants entering Leon Creek.	Authorization to discharge COCs in groundwater to surface water at levels above surface water quality standards may be subject to the permitting requirements of Chapter 305, and likely would require a modification to the existing permit.	The rule provides clear guidance on the use of a dilution factor when assessing groundwater discharge to surface waters. The final list of COCs may be reduced significantly if a site-specific dilution factor is incorporated into the cleanup level calculation.	

**TABLE 4.4 (Continued)**  
**ISSUES TO CONSIDER IN SELECTING A REGULATORY OPTION**  
**SITE LF014 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

1993 Texas Risk Reduction Rule (RRR)		1999 Texas Risk Reduction Program (TRRP)	
Pro	Con	Pro	Con
	The horizontal and vertical extent of contamination must be characterized to background levels.	A single set of risk levels apply regardless of remedy standard used. Individual carcinogen: 1E-05; Cumulative risk level: 1E-04; Individual noncancer hazard: 1 Cumulative noncancer hazard: 10 These levels are potentially less conservative than the RRR levels.	
There is no detailed process provided in the rule as to how and when to perform an ecological evaluation. However, the TRRP ecological risk assessment program may be required.	More stringent cleanup levels than human health values will be required, if necessary, to protect ecological receptors. Terrestrial ecological receptors also may need to be evaluated (surface water quality criteria only protect aquatic life)		
	Though there is some flexibility under the RRR standards, target risk and hazard levels generally are: Individual carcinogen: 1E-06; Cumulative risk level: 1E-04; Individual noncancer hazard: 1 Cumulative noncancer hazard: 1		

## **SECTION 5**

### **EVALUATION OF REMEDIAL SYSTEM**

The results of SAIC's 1998 evaluation of the effectiveness of the existing RW and treatment system are described in Section 1.4.7. The revised groundwater model prepared for the 1998 system evaluation indicated that the current system is providing little containment of the CAH plume. As a result, the Base is evaluating replacement of the existing 14-RW system at Site LF014 with a groundwater extraction trench, as shown on Figure 1.12. The objective of the extraction trench would be to prevent exceedances of surface water quality standards in Leon Creek due to discharge of contaminated groundwater. The Base also is considering installing a soil vapor extraction (SVE) system in the northwestern portion of the site in an attempt to reduce the contaminant source, and performing regrading/revegetation of the site to minimize precipitation infiltration and resultant leachate generation (Figure 1.12). The effectiveness of SVE at remediating the source is uncertain due to the unknown nature and location(s) of the source. For example, containers of pure-phase solvent would not be effectively remediated, nor would residual solvents or dense nonaqueous-phase liquids (DNAPLs) in the capillary fringe and below the water table. As described in Section 1.3, landfill trenches were excavated to depths of 8 to 12 feet bgs; therefore, it is possible that some of the landfilled wastes are below the average water table, which occurs at a depth of approximately 8 feet bgs.

The potential for application of emerging technologies is an important part of the RPO evaluation. Consequently, as part of the Site LF014 RPO investigation, promising innovative technologies were identified and evaluated for their potential application to interception of the contaminant plume near the edge of Leon Creek. This evaluation has been conducted and presented in the format of a brief focused feasibility study (FFS), which identifies a limited number of potentially applicable technologies and ranks them according to criteria of protectiveness of human health and the environment, implementability, regulatory/community acceptance, and cost. Technologies evaluated include an actively pumped extraction trench, a permeable reactive barrier (e.g., zero-valent iron wall), and an air sparging curtain.

All of the evaluated remedial alternatives are designed to intercept the CAH plume near its edge in order to protect Leon Creek from discharge of contaminated groundwater. Even if an SVE system is installed in the source area, the persistence of the contaminant sources is unknown. Therefore, the required future duration of downgradient plume interception also is not known. Due to the potential persistence throughout the plume of dissolved contaminant concentrations that exceed RGs, maintenance of institutional controls will be required under all alternatives to prevent significant exposure of potential receptors to contaminated site media.

## **5.1 EVALUATION OF THE NEED FOR PLUME CONTAINMENT**

Intentional releases of contaminants exceeding applicable surface water standards into waters of the State (including Leon Creek) is a violation of Chapter 26 of the Texas Water Code. Therefore, a remedial alternative consisting solely of monitored natural attenuation (MNA) does not appear to be an option for Site LF014 unless it can be demonstrated to the satisfaction of TNRCC that dilution/mixing of contaminants discharging to the creek would prevent exceedance of state surface water and sediment standards. Regulatory options for demonstrating the impact of dilution were discussed in Section 4. Nonetheless, MNA should be a component of any engineered remedial alternative implemented. Periodic monitoring of groundwater and surface water quality will allow assessment of whether, and how rapidly, the contaminant source is diminishing over time, and will provide ongoing confirmation of the effectiveness of the plume-interception system at preventing discharge of contaminants to Leon Creek.

## **5.2 DATA NEEDS**

Determination of a representative hydraulic conductivity for the remedial alternatives under consideration is a significant data need for this site. The hydraulic conductivity of the gravel zone overlying the Navarro Clay may range up to 1,600 ft/day based on pump test results reported by SAIC (1998). Overall, hydraulic conductivities reported for the site range over more than three orders of magnitude (Section 1.5.2). As described in Section 4.3.1, accurate quantification of this parameter will aid in determining the degree to which contaminants are diluted upon entering the creek. Quantification of dilution effects also will facilitate determination of the proper location and length of a downgradient plume-intercept system.

Accurate quantification of the hydraulic conductivity of the gravel zone and the groundwater velocity within this zone is critical to design of the required flow-through thickness of a permeable reactive barrier. Therefore, if further evaluation of this alternative is desired, additional aquifer testing and numerical modeling of the groundwater flow system is recommended to further refine the magnitude of this critical design parameter. If groundwater velocities are sufficiently high to impact the size of a remediation system (e.g., the required thickness of a permeable reactive barrier), then hydraulic manipulation/control to limit groundwater flux could be evaluated as a means of reducing the overall treatment cost. For example, a collection trench or barrier wall system could be installed upgradient from the contaminated area to divert groundwater away from the source area.

A potential requirement for treatment of metals in groundwater in addition to CAHs also significantly impacts the evaluation of remedial alternatives. The need for metals treatment should be evaluated as described in Section 4.3.

## **5.3 EVALUATION OF ENGINEERED PLUME CONTAINMENT ALTERNATIVES**

The current extraction well system does not appear to be providing adequate containment of the groundwater plume because the capture zones of the extraction wells do not overlap (Section 1.4.7). A groundwater collection or treatment (e.g., iron filings or air sparging) trench would provide improved containment of the groundwater plume

(SAIC, 1998). The groundwater collection/treatment trench would be located to intercept the portion of the plume containing dissolved contaminant concentrations that, upon discharge to Leon Creek and subsequent dilution, could still cause surface water standards to be exceeded in the creek. For costing purposes, it is assumed that a trench would be approximately 800 feet long and would be installed at the location shown on Figure 1.12.

It is recommended that approximately 450 feet of the downgradient (southwest) wall of the trench be lined with a vertical geomembrane barrier to control the influence of Leon Creek on groundwater collection/treatment. This vertical barrier would be located approximately from well LF014RW032 to LF014RW037, which is the area along the ponded portion of Leon Creek that has a very low groundwater gradient (Figure 3.4). The installation of the vertical barrier is considered to be important for minimizing the removal and/or treatment of creek water through the collection/treatment trench, which would generally increase costs of operation.

The trench would be keyed at least 1 foot into the top of the Navarro Clay at an estimated average depth of approximately 20 feet bgs. The trench would be backfilled with permeable material such as sand, gravel, or iron filings as required for the three remedial alternatives discussed in the following subsections.

### **5.3.1 Alternative 1 – Groundwater Extraction Trench**

Under this alternative, the groundwater collection trench would be filled with a permeable sand to a minimum of 2 feet above the water table. A sand backfill (e.g., concrete sand) is recommended to provide a permeable backfill for groundwater removal, as well as to provide filtration of fine silt and clay size particles into the backfill. A perforated collection pipe would be installed near the bottom of the trench to facilitate collection of groundwater. Submersible pumps would be installed within vertical risers located at two sump locations, and pumped groundwater would be conveyed to the existing Zone 1 groundwater treatment plant (GWTP) via the existing pipeline system. The pumping rate would be sufficient to capture groundwater entering the trench, but complete dewatering or more enhanced drawdown in the trench would not be performed, in order to minimize the groundwater extraction rates. Rather, the natural groundwater flow gradient would be relied upon to deliver water and dissolved contaminants to the trench. Pumping to an elevation of approximately 620 feet amsl is recommended to provide capture of the plume.

#### **5.3.1.1 Effectiveness and Protectiveness of Human Health and the Environment**

A laterally continuous gravel-filled groundwater extraction trench that is actively pumped would constitute a highly effective barrier to plume migration. All dissolved COCs entering the trench, including VOCs, SVOCs, and metals, would be intercepted. It should be noted that the current Zone 1 GWTP does not include a treatment step for metals. A low-permeability geomembrane within the trench would ensure hydraulic control of the area of ponded water along Leon Creek. Therefore, Leon Creek (and related human and ecological receptors) would be afforded a high degree of protection from discharge of site contaminants. Minimizing the pumping rate to that required for capture of groundwater entering the trench under the natural hydraulic gradient would minimize the quantity of water requiring treatment at the treatment plant.

### 5.3.1.2 Regulatory/Community Acceptance and Implementability

Regulatory and community acceptance of this alternative should be positive due to the anticipated high degree of effectiveness of an extraction trench at protecting Leon Creek. The area selected for the trench is on Base property that is either undeveloped or (in the case of the golf course) has been disturbed in the past during installation of the current extraction well system. Any impact to golf course activities would be relatively short-term, and the ground surface would be restored to its original condition following trench installation. The current groundwater extraction and monitoring wells would be used for upgradient system monitoring. No other subsurface obstructions or utilities are believed to be present along the proposed trench line (Figure 1.12).

The soil to be excavated includes sand and gravel layers up to approximately 8 feet thick that may cave during open-trench excavation activities. Therefore, if a backhoe is used, shoring or trench boxes likely would be required. However, a one-pass continuous-trenching machine is recommended for installation. Such a machine could excavate and install the sand backfill and a flexible, perforated drain pipe wrapped in filter fabric in a single pass; therefore shoring would not be required. Disposal of excavated (contaminated) soil that is replaced with the sand backfill would be required. Alternatively, the soil could be characterized and potentially used as fill material elsewhere on the Base.

Available geologic data indicate that the Navarro Clay surface is not flat, but has been eroded into a series of swells and swales (Figure 3.1). The trench must be fully keyed into the Navarro Clay to prevent underflow of contaminants. Based on the unindurated nature of the Navarro Clay, problems with excavating into the clay layer are not anticipated.

This alternative is a reliable and proven method for capturing and disposing of contaminated groundwater, and relies on conventional technologies. The implementation of these technologies has been well demonstrated in numerous full-scale applications across the US. Site-specific implementation of this alternative would require design and installation, and a commitment to O&M of the extraction system over a potentially lengthy period. However, it is likely that O&M of this proposed collection trench would be less costly than the current O&M requirements for the multiple well system due to maintenance of only two pumps associated with the collection trench. The extracted groundwater would be routed to the current Zone 1 GWTP via the existing pipeline system installed for the interim extraction system. This alternative has less potential for precipitation of solids and potential fouling of the collection trench than any of the three alternatives evaluated.

This alternative involves the use of easily obtainable equipment (e.g., submersible pumps) and materials (piping, etc.). O&M activities associated with the implementation of this alternative would include periodic inspection and monitoring of system operations, periodic replacement of pumps, groundwater monitoring, and periodic reporting to TNRCC. Submersible pumps are generally highly reliable when properly maintained. The most frequent reliability problems occur with pump controls, which must be carefully set to minimize pump cycling. In addition, periodic cleaning of the horizontal, perforated drain pipe installed near the base of the trench may be required due to accumulation of sediment. This cleaning could be performed by a local sewer cleaning contractor using a

jetting tool, and would not represent a significant implementability concern. Any future land use plans should include protection of the extraction trench and network of LTM wells.

### 5.3.1.3 Cost

The estimated capital and OM&M costs of Alternative 1 are shown in Table 5.1. The total cost of a groundwater collection trench under Alternative 1 is approximately \$4,162,000. The cost was calculated using a current cost approach (e.g., the current cost to implement an activity with an annual cost of \$1,000 over a period of 30 years is \$30,000). It is assumed that the collection trench would be operated for 30 years after installation, and that excavated soil would be used as cover material at an on-Base landfill. A continuous-trenching machine would be used for placement of the collection trench, and for placement of the vertical barrier geomembrane. The estimated annual OM&M cost of \$125,000 includes semiannual LTM for 30 years, pump replacement every 5 years, and jetting to clean out the collection pipe every 3 years. Based on information provided by Kelly AFB, it was assumed that the current annual O&M and water treatment cost for the LF014 extraction well system is \$100,000. It was also assumed that the cost to maintain an extraction trench would be 80 percent of the current O&M/treatment cost due to the lesser number of extraction wells and pumps. Therefore, an annual O&M/treatment cost of \$80,000 was used for Alternative 1. It was assumed that the extra cost to treat the anticipated increased flow from the extraction trench would not be sufficient to offset the reduction in O&M costs.

Detailed cost summaries are provided in Appendix B.

**TABLE 5.1**  
**ESTIMATED COSTS FOR ALTERNATIVE 1**  
**SITE LF014 CONTAMINANT PLUME**  
**KELLY AFB, TEXAS**

Total Capital Costs	\$426,551
Annual OM&M	<u>\$101,820</u>
Total Current Cost of Alternative (30 years) <sup>a/</sup>	\$3,481,000

<sup>a/</sup> Capital cost + (annual OM&M cost x 30 years).

### 5.3.2 Alternative 2: Permeable Reactive Barrier

A permeable reactive subsurface barrier is defined by Powell and Powell (1998) and Powell and Puls (1997) as:

*“...an emplacement of reactive materials in the subsurface designed to intercept a contaminant plume, provide a flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals downgradient of the barrier.”*

The majority of installed permeable reactive barriers use zero-valent iron as the reactive media for converting contaminants to non-toxic or immobile species. Iron metal has the ability to reductively dehalogenate hydrocarbons, such as converting TCE to ethene. It can also reductively precipitate anions and oxyanions, such as converting soluble hexavalent chromium oxides to insoluble trivalent chromium hydroxides. With an iron filings trench, groundwater contaminated with CAHs flows through granular, zero-valent iron in a trench, which is excavated perpendicular to the axis of groundwater flow. Dissolved CAHs are degraded through a series of less-chlorinated intermediates to nontoxic, nonchlorinated end products. It is possible to shorten the trench length using “funnel walls” constructed using sheet piling, slurry walls, or geomembrane curtains to direct water into the iron filings trench. This is often referred to as the funnel-and-gate method. EnviroMetal Technologies, Inc. (ETI) of Waterloo, Ontario, Canada has been granted exclusive rights for commercialization of this patented zero-valent iron technology by the patent holder, the University of Waterloo. Site-specific information was forwarded to ETI to obtain an assessment regarding application of this technology at Site LF014. ETI’s assessment, together with the site-specific information submitted to them, are included in Appendix B.

The location of a proposed subsurface barrier wall and iron filings trench would be the same as the groundwater extraction trench location described for Alternative 1 and shown on Figure 1.12. The system would be placed near the creek, with a subsurface barrier located along the northwestern length of the trench, as described in Section 5.3. This barrier wall would minimize infiltration of ponded water along Leon Creek. Similar to the groundwater extraction trench, the subsurface barrier wall and iron filings trench would be keyed into the Navarro Clay to prevent underflow of contaminated groundwater.

### **5.3.2.1 Effectiveness and Protectiveness of Human Health and the Environment**

Historical groundwater sampling results, including those obtained by Parsons ES in January 2000, indicate that the primary organic COCs in groundwater near Leon Creek are TCE, *cis*-1,2-DCE, and VC. In addition, the VOC acetone (residential ingestion standard of 2,400 µg/L) was detected at a concentration of 2,820 µg/L in groundwater from one TW in January 2000, and the SVOC bis(2-ethylhexyl)phthalate (ingestion-based standard of 6 µg/L) was detected at concentrations ranging up to 10 µg/L at several locations across the site. A single detection of the SVOC pentachlorophenol (ingestion-based standard of 1 µg/L) occurred near the creek in April 1998; the detected concentration was 3 µg/L. Several other organic compounds (e.g., benzene, 1,4-DCB) have been detected in portions of the landfill that are more distant from Leon Creek; however, available data suggest that these compounds are not present near the creek, and therefore do not appear to be discharging to the creek at concentrations of concern.

Information obtained from prior applications of iron filings trenches indicates that metal-enhanced reductive dehalogenation would degrade the TCE, *cis*-1,2-DCE, and VC present in the site groundwater to non-toxic chemicals, and prevent discharge of these compounds to Leon Creek at concentrations exceeding surface water standards. The ETI process has been successfully applied at several sites where these CAHs are the primary COCs. To date, the technology has not degraded acetone, pentachlorophenol, or bis(2-ethylhexyl)phthalate. However, acetone is a common laboratory contaminant and may not actually be present in site groundwater at concentrations exceeding surface water

standards. This observation is supported by the fact that only one detection of this compound during a single sampling event (January 2000) exceeded a groundwater or surface water quality standard. The maximum detected concentration of bis(2-ethylhexyl)phthalate (10 µg/L), only slightly exceeded the groundwater and surface water ingestion standard for this compound of 6 µg/L, and this compound does not appear to pose a significant threat to the integrity of Leon Creek. bis(2-ethylhexyl)phthalate also is a common laboratory contaminant.

Previous sampling results indicate that concentrations of TCE, *cis*-1,2-DCE, and VC that would enter the iron filings wall would range up to approximately 500 µg/L, 425 µg/L, and 340 µg/L, respectively. Based on previous laboratory and field results, ETI estimates that a residence time of about 2 days would be required to reduce the maximum-detected concentrations (along the current extraction well line) of TCE, *cis*-1,2-DCE, and VC detected in site groundwater to below 5 µg/L, 70 µg/L, and 2 µg/L, respectively. An average natural groundwater velocity in the vicinity of the current groundwater extraction system of 1.1 to 3.6 feet per day (ft/day) was computed using the following parameter values:

- Hydraulic gradients ranging from 0.009 ft/ft to 0.03 ft/ft (Figure 3.4);
- An average hydraulic conductivity of 24 ft/day (geometric mean of the values presented by SAIC (1998); and
- An assumed average effective porosity of 0.2.

Based on this range of groundwater velocities, an iron zone having a flow-through thickness of approximately 2.2 to 7.2 feet would theoretically provide the required residence time. The reduction of VC concentrations to less than 2 µg/L is the principle reason for the required wall thickness. The analysis performed by ETI indicated that concentrations of TCE and *cis*-1,2-DCE would be reduced to below 5 µg/L and 70 µg/L, respectively, within about 20 hours of residence time. In contrast, the maximum VC concentration would still be approximately 45 µg/L after 20 hours. The effects of the iron filings wall on removal of chromium, selenium, and lead are assessed in the following paragraph.

According to ETI, the iron filings wall could efficiently treat concentrations of chromium and selenium dissolved in site groundwater. The estimated residence time required to treat the VOCs (2 days) also should be sufficient to remove the chromium and selenium in the iron zone. Treatment of other metals of potential concern, such as lead, would require addition of an organic treatment medium to the trench (e.g., compost). The mechanism of dissolved metals removal in an organic treatment medium is based on biotic sulfate reduction to sulfide, and consequent precipitation of metals as sulfide complexes. The organic treatment medium could be mixed with pea gravel as necessary to increase porosity. ETI's preliminary review of the site data indicated that a residence time of approximately 1 day in the compost/pea gravel zone may be required for the removal of dissolved metals detected in the site groundwater.

Performance of laboratory treatability tests prior to a final decision to implement a permeable reaction wall technology is recommended to provide information concerning potential mineral precipitation in the reactive material caused by changing ORP and pH

conditions. According to ETI, the iron material itself should last for several years to decades. The precipitates, if significant, will form in a narrow zone at the upgradient aquifer/iron interface. To date, ETI reports that there is no evidence of sliming or plugging in commercial *in situ* systems operating successfully for over 5 years; however, landfill leachate from the LF014 site may have a more significant potential for media plugging than the commercial systems evaluated. The treatability testing also would more precisely determine VOC and metal removal rates and further refine the residence-time requirements in the treatment zones.

### **5.3.2.2 Regulatory/Community Acceptance and Implementability**

The iron filings trench should prevent discharge of TCE, *cis*-1,2-DCE, VC, chromium, and selenium to Leon Creek at concentrations exceeding surface water standards. If desired, an organic medium could be added to treat other metals of potential concern; therefore, regulatory and community acceptance of this alternative is anticipated to be high.

The implementability issues related to trenching at Site LF014 discussed in Section 5.3.1.2 would also apply to Alternative 2. Since 1994, 48 permeable walls containing granular iron have been installed to remediate VOCs in groundwater. There are currently 31 full-scale *in situ* systems removing VOCs from groundwater, in addition to 17 pilot-scale systems that have been installed to provide “proof-of-concept” data and to demonstrate innovative construction methods (see Appendix B). Continuous trenching would be a viable construction technique for installation of the barrier wall and the iron filings wall.

Implementation of a permeable reactive barrier may change the oxidation/reduction potential of the aquifer by addition of the zero-valent iron media. Since the groundwater flowing into the trench is likely to be impacted by landfill leachate, there may be significant precipitation and potential fouling of the media in the trench. If this fouling is significant, then periodic replacement of the iron media may be required. Initial bench-scale treatability testing of the reaction mechanisms for site contaminants, as well as fouling potential of site waters, would be recommended during the design stage.

Generally speaking, the only OM&M activity required for a permeable reactive barrier would be groundwater and surface water quality monitoring to assess the effectiveness of the system at removing dissolved contaminants. The major factor affecting OM&M costs is the possible need for periodic rejuvenation of iron sections affected by precipitates. According to ETI, rejuvenation could involve agitating the upgradient face of the iron every 7 to 10 years with an auger to restore the permeability of this material.

Because the groundwater FS has already been finalized and accepted by the TNRCC, installation of a permeable reactive barrier may require revision of the FS and the ROD. In contrast, implementation of a groundwater extraction trench may not require revision of these documents because the approved remedy incorporates groundwater extraction. Therefore, an iron filings trench could not be implemented as rapidly as a groundwater extraction trench (Alternative 1).

### 5.3.2.3 Cost

The estimated capital and OM&M costs of Alternative 2 are shown in Table 5.2. The total cost of a permeable reaction wall under Alternative 2 is approximately \$4,340,000. The cost was calculated using a current cost approach (e.g., the current cost to implement an activity with an annual cost of \$1,000 over a period of 30 years is \$30,000).

The cost of this system is based on an estimate provided by ETI, the exclusive vendor for this technology (see Appendix B). The estimated cost is very sensitive to the amount of iron filings to be placed in the trench, which is based on the assumed groundwater velocity that is representative of the site. A relatively rapid groundwater velocity of 3.6 ft/day was assumed for this estimate, which would require a barrier thickness of 7.2 feet. However, assuming the lower range of 1.1 ft/day for groundwater velocity (required barrier thickness of 2.2 feet) could reduce the estimated iron filings material costs by approximately \$1,300,000, and reduce construction costs by approximately \$175,000. The estimated cost assumes treatment of maximum-detected concentrations of VOCs (along the line of groundwater extraction wells) to drinking water standards. Material and construction costs could be further reduced if a lower level of treatment was acceptable due to the recognized effects of dilution and volatilization in Leon Creek, and/or if the trench width were varied with the dissolved VOC concentrations. Approximately \$250,000 of capital cost is associated with installation of an additional trench filled with compost for treatment of metals in groundwater. The necessity of treating for metals has not been established with certainty (see recommendations 2 and 5, Section 7).

As described for Alternative 1, it was assumed that the permeable reactive barrier would be operated for 30 years after installation, and that excavated soil would be used as cover material at an on-Base landfill. A continuous-trenching machine would be used for placement of the iron filings material, and for placement of the vertical barrier geomembrane. OM&M would include semiannual LTM for 30 years, and refurbishing the upgradient face of the wall with auger drilling every 10 years to minimize potential problems with precipitation buildup. Detailed cost summaries are provided in Appendix B.

This cost of this alternative is similar to that of Alternative 1. A potentially significant cost component that is reflected in this estimate is the savings associated with passive treatment of the water, rather than conveying the water to the treatment plant as assumed under Alternative 1. Because the flow of groundwater from Site LF014 is currently only a portion of the flow to the treatment plant, it was assumed that operation of the plant would still be required even upon implementation of this alternative. As stated in Section 5.3.1.3, the estimated annual O&M and water treatment cost for the current LF014 extraction well system is \$100,000. In addition, construction of a new groundwater treatment plant for Zone 1 reportedly will be required within the next three years.

**TABLE 5.2**  
**ESTIMATED COSTS FOR ALTERNATIVE 2**  
**SITE LF014 CONTAMINANT PLUME**  
**KELLY AFB, TEXAS**

Total Capital Costs	\$3,318, 201
Annual OM&M	<u>\$34,127</u>
Total Current Cost of Alternative (30 years) <sup>a/</sup>	\$4,342,000

<sup>a/</sup> Capital cost + (annual OM&M cost x 30 years).

### 5.3.3 Alternative 3: Air Sparging Curtain

An air sparging curtain could be constructed by installing a horizontal, perforated pipe in the bottom of a gravel-filled trench excavated to the Navarro Clay. Air injected into the pipe would rise through the porous trench backfill and strip VOCs from the groundwater, transferring them into the vadose zone. If necessary to meet air quality standards, SVE and an aboveground air treatment system could be installed to capture and treat the stripped VOCs. Based on the shallow depth to groundwater and the presence of the golf course, capture and treatment of the stripped VOCs may be necessary, at least in the area frequented by golfers. The SVE system would be constructed within the unsaturated portion of the gravel-filled trench. A subsurface barrier wall would be placed along the northwestern length of the trench as discussed for Alternatives 1 and 2 to minimize infiltration of ponded water along Leon Creek.

#### 5.3.3.1 Effectiveness and Protectiveness of Human Health and the Environment

Some researchers have cast doubt on the long-term effectiveness of air sparging. Problems such as channeling, which consists of preferential migration of injected air along specific (more-permeable) flow paths rather than uniform air dispersal in the zone surrounding the perforated pipe, have been cited. The occurrence of channeling could reduce the integrity of the sparging curtain in some areas, and allow contaminants to migrate past the curtain. However, the potential for channeling in the proposed homogeneous, gravel-filled trench is reduced. Therefore, concentrations of VOCs in groundwater migrating through the trench should be substantially reduced to near or below surface water quality standards. Concentrations of any VOCs that discharge to the creek should be rapidly reduced to below surface water standards as a result of dilution, volatilization, and photodegradation.

A small percentage of the injected air would most likely become dissolved in the groundwater, increasing the DO content within the sparging trench and for some distance downgradient from the trench. DO represents an alternate electron acceptor that, if used preferentially over CAHs, may inhibit the occurrence of reductive dehalogenation near the creek. However, aerobic biodegradation of VC and possibly also *cis*-1,2-DCE would be enhanced.

Unlike a groundwater extraction trench or permeable reaction wall, implementation of air sparging would not significantly reduce concentrations of SVOCs or metals in groundwater. However, the relatively aerobic, oxidizing environment present in the sparging trench potentially could promote precipitation of ferrous iron and other inorganic constituents in the trench, reducing both the porosity of the gravel backfill and the effectiveness of the system over time. Therefore, a pre-design evaluation of the groundwater chemistry and the effects of aeration on precipitation of solids is recommended prior to implementation. As part of this evaluation, the mass of dissolved metals that could potentially precipitate in the trench could be estimated and compared to the available void volume in the trench to assess the significance of this issue.

### **5.3.3.2 Regulatory/Community Acceptance and Implementability**

Regulatory/community acceptance of an air sparging curtain should be high if the site remedial objective is to prevent exceedance of surface water standards for VOCs in Leon Creek. Conversely, if it is determined that other substances (e.g., metals) also require remediation, then acceptance of an air sparging curtain would be low relative to a groundwater extraction trench or permeable reactive barrier.

The implementation of air sparging technology has been demonstrated in numerous full-scale applications. Air sparging can effectively remove VOCs from groundwater as long as subsurface materials are sufficiently permeable and homogeneous. A site-specific air sparging pilot test would not be required if a horizontal sparging well is installed in a gravel-filled trench.

Implementation of air sparging would significantly change the oxidation/reduction potential in the aquifer by addition of injected air. Since the groundwater flowing into the trench is likely to be impacted by landfill leachate, there is likely to be significant precipitation and potential fouling of the gravel in the trench. Periodic replacement of the trench gravel may be required. Initial bench-scale treatability testing of the fouling potential of site waters would be recommended during the design stage to better assess the potential impact of fouling of the gravel by precipitation of solids.

Similar to the alternatives described in Sections 5.3.1 and 5.3.2, installation of an air sparging curtain at Site LF014 would involve trenching to the Navarro Clay surface. Therefore, the trenching-related implementability issues described in those sections also would apply to construction of an air sparging trench.

Additional, relatively shallow trenching would be required to connect the horizontal sparging well to a central location containing blowers and controls. This alternative would involve mobilization of conventional, commercially-available equipment (e.g., trenching equipment) that is expected to have minimal impacts on Base or golf course operations. There are multiple contractors experienced in the installation of these types of systems. LTM of groundwater would be required to verify the effectiveness of the system during operation.

Installation and operation of an air sparging/SVE system would require a commitment of labor hours and other resources to maintain and monitor the system. Weekly system checks are recommended, and operating data such as air-injection pressures and extraction vacuum and flow rates would be manually recorded. Other OM&M activities

would include periodic blower inspection and maintenance, periodic measurement of DO levels in groundwater, and replacement of any failed or worn equipment. In addition, an air emissions permit may be required prior to system startup. Vapor treatment (such as activated carbon adsorption) likely could possibly be required for the offgas from the SVE system. LTM of contaminants in groundwater and surface water also would be required.

Because the groundwater FS has already been finalized and accepted by the TNRCC, installation of an air sparging curtain may require revision of the FS and the ROD. In contrast, implementation of a groundwater extraction trench may not require revision of these documents because the approved remedy incorporates groundwater extraction. Therefore, an air sparging curtain could not be implemented as rapidly as a groundwater extraction trench (Alternative 1).

### **5.3.3.3 Cost**

The estimated capital and O&M costs of Alternative 3 are shown in Table 5.3. The total cost of an air sparging treatment trench under Alternative 3 is approximately \$3,480,000. The cost was calculated using a current cost approach (e.g., the current cost to implement an activity with an annual cost of \$1,000 over a period of 30 years is \$30,000). The cost of this alternative is very similar to that of Alternative 1, and approximately \$900,000 less than Alternative 2.

As for Alternative 1, it is assumed that the air sparging treatment wall and SVE system would be operated for 30 years after installation, and that excavated soil would be used as cover material at an on-Base landfill. A continuous-trenching machine would be used for placement of the permeable backfill and the vertical barrier geomembrane. Carbon adsorption was assumed for treatment of the SVE offgas. OM&M would include quarterly replacement of carbon for the SVE system, semiannual LTM for 30 years, and replacement of the air sparging and SVE blowers every 10 years. Due to potential clogging of the trench due to precipitation, it was assumed that the trench gravel would require replacement every 5 years. Detailed cost summaries are provided in Appendix B. Note that if SVE was not required, the capital costs of Alternatives 1 and 3 would be similar.

As described for Alternative 2, a significant cost component that is reflected in this estimate is the savings associated with passive treatment of the water, rather than conveying the water to the treatment plant as assumed under Alternative 1. Because the flow of groundwater from Site LF014 is currently only a portion of the flow to the treatment plant, it is assumed that the plant would still be required even upon implementation of this alternative.

**TABLE 5.3**  
**ESTIMATED COSTS FOR ALTERNATIVE 3**  
**SITE LF014 CONTAMINANT PLUME**  
**KELLY AFB, TEXAS**

Total Capital Costs	\$474,451
Annual OM&M	<u>\$100,235</u>
Total Current Cost of Alternative (30 years) <sup>a/</sup>	<u>\$3,482,000</u>

<sup>a/</sup> Capital cost + (annual OM&M cost x 30 years).

#### 5.4 SUMMARY AND CONCLUSIONS

The following significant observations are derived from the analysis of remedial alternatives presented in this Section:

- An air sparging trench appears to be one of the least-cost alternatives. However, installation of an aeration trench in a reducing environment can cause precipitation of metals with resultant fouling/permeability reduction. Therefore, the long-term effectiveness of this alternative is questionable, and periodic replacement of the trench may be required. The cost provided in Table 5.3 assumes replacement of the trench backfill every five years.
- Based on current conditions, a groundwater extraction trench also appears to have cost advantages. However, the true cost of an extraction trench may be significantly greater than shown in Table 5.1 because construction of a new groundwater treatment plant for Zone 1 (which may not be required if a passive treatment system is installed) reportedly will be required within the next three years.
- The cost of an iron filings wall presented in Table 5.2 may be excessively conservative because it assumes a uniform wall thickness of 7.2 feet, which is unusually thick for these types of systems. More detailed analysis of groundwater velocities, use of average dissolved contaminant concentrations rather than maximum concentrations, and/or bench-scale testing may indicate that a smaller overall volume of iron is appropriate.
- Installation of an iron filings wall or an air sparging trench may require revision of the FS and the ROD, and would therefore delay the implementation of an alternative groundwater remedy at Site LF014.

These observations suggest that an iron filings wall could provide adequate treatment of VOCs migrating toward Leon Creek, and substantially reduce future O&M costs. Therefore, if the remedial schedule permits, installation of an iron filings wall at LF014 should be evaluated in more detail prior to making a final decision regarding the groundwater remedy.

## **SECTION 6**

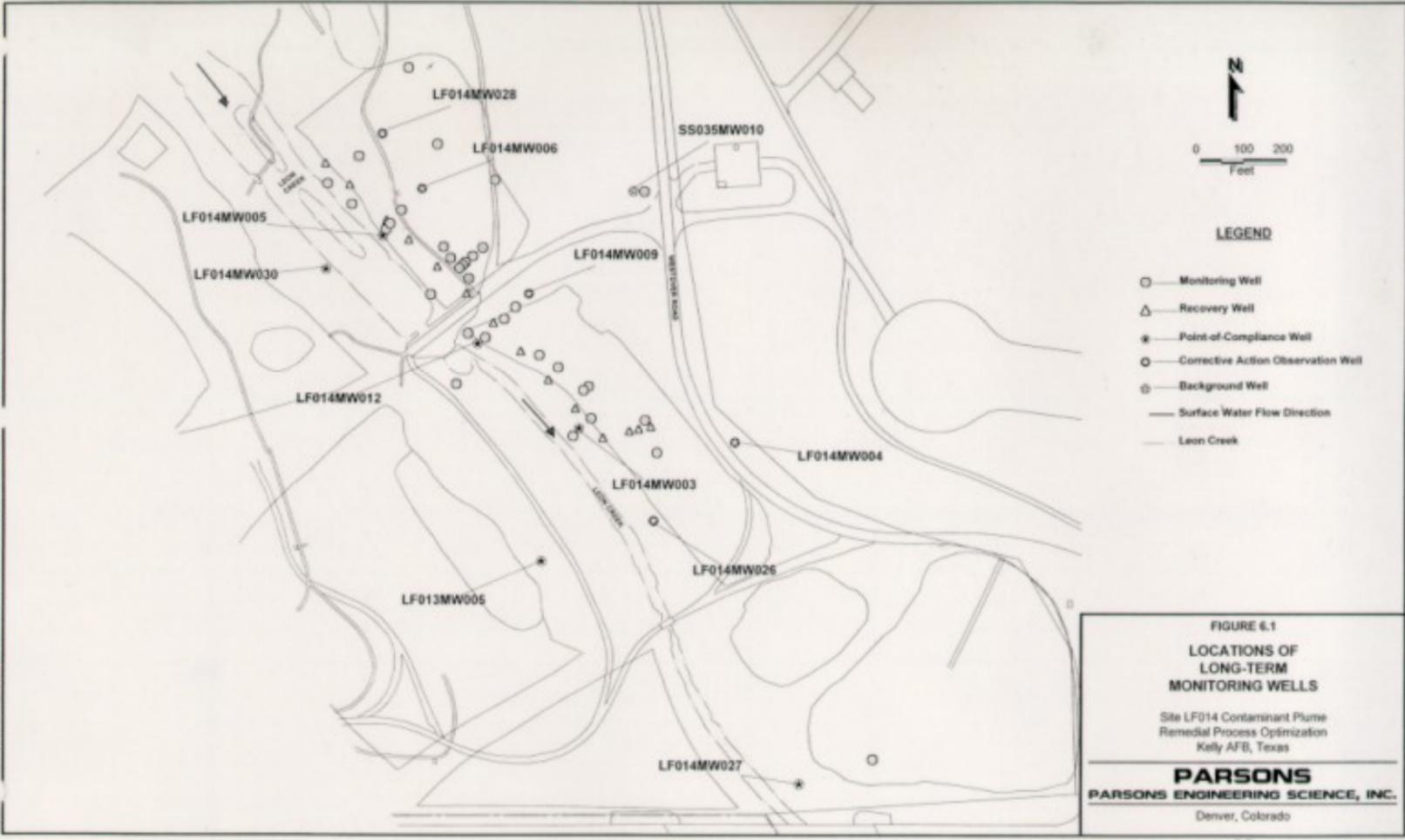
### **MONITORING PROGRAM EVALUATION**

Designing an effective monitoring program involves locating groundwater monitoring wells and developing a site-specific groundwater sampling and analysis strategy. The monitoring program should be designed to monitor plume migration over time and to verify that the implemented remedial alternative is effectively protecting onsite and potential downgradient receptors. The design of the monitoring program should include consideration of existing exposure pathways, as well as exposure pathways arising from potential future use of the groundwater.

Performance monitoring wells, located upgradient, within, and just downgradient from the plume, are used to verify the effectiveness of the remedial system relative to the performance criteria. LTM of these wells also provides data to detect migration of the plume and define trends in contaminant concentrations over time. A contingency monitoring well downgradient from the plume is used to ensure that the plume is not migrating beyond the containment system and to trigger a contingency remedy if contaminants are detected. Primary factors to consider are (at a minimum) distance to potential receptor exposure points, groundwater seepage velocity, types of contaminants, aquifer heterogeneity, surface water impacts, and the effect of the remediation system. These factors will influence well spacing, analytical protocols, and sampling frequency. Typically, the faster the seepage velocity and the shorter the distance to receptors, the greater the sampling frequency. One of the most important purposes of LTM is to confirm that the contaminant plume is behaving as predicted. Visual and statistical tests can be used to evaluate plume stability. The LTM data for groundwater remediation systems should demonstrate a clear and meaningful downward trend at appropriate monitoring points.

#### **6.1 CURRENT MONITORING PLAN**

Currently, the LTM plan for Site LF014 consists of annual sampling of 12 monitoring wells, including point-of-compliance (POC) wells, corrective-action observation wells, and a background well (Table 1.1). The Kelly AFB Compliance Plan for Zone 1 (TNRCC, 1998) requires that POC wells LF014MW005, LF014MW012, and LF014MW003 be monitored annually (Figure 6.1). Wells LF014MW005 and LF014MW012 are screened in the surficial aquifer near the northern bank of Leon Creek. Well LF014MW003 also is located along the northern bank of Leon Creek, but is screened in the Navarro Clay. In addition to the three wells mandated for monitoring in the Compliance Plan, nine additional wells associated with Site LF014 or adjacent sites have been chosen by the Base and the sampling contractor for annual sampling (Figure 6.1).



**FIGURE 6.1**  
**LOCATIONS OF**  
**LONG-TERM**  
**MONITORING WELLS**  
 Site LF014 Contaminant Plume  
 Remedial Process Optimization  
 Kelly AFB, Texas  
**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**  
 Denver, Colorado

Samples from LTM wells are analyzed for VOCs, SVOCs, total metals, pesticides/PCBs, and cyanide. In addition, two RWs (though not the same wells every event) are sampled, and a composite sample of the recovery system outflow (influent to treatment plant) is collected annually, typically in May. These samples are analyzed for the same analytes as the 12 LTM wells, plus sulfide.

## 6.2 GEOSTATISTICAL ANALYSIS

Statistical techniques can be applied to the design and evaluation of monitoring programs to assess the quality of information generated during monitoring, and to optimize monitoring networks. Parsons ES examined monitoring data collected during April and May 1998 using geostatistical techniques in a screening-level evaluation of the monitoring network currently utilized at Site LF014.

Geostatistics, or the theory of regionalized variables (Clark, 1987; Rock 1988; American Society of Civil Engineers [ASCE], 1990a and 1990b), is used to evaluate relationships among variables that have values dependent on location and that are continuous in space, but which vary in a manner too complex for simple mathematical description. The theory of regionalized variables is based on the premise that the differences in values of a spatial variable depend only on the distances between sample locations and the relative orientations of sample locations. In other words, the values of a variable (e.g., concentrations of TCE) measured at two locations that are spatially "close together" will be more similar than values of that variable measured at two locations that are "far apart". If the known sample values are used, the value of the variable (e.g., chemical concentrations) at any point within the sampled region can be estimated via a process known as "kriging" (Clark, 1987; ASCE, 1990a and 1990b).

An additional advantage of kriging as an estimation technique is that the standard deviations (errors) associated with the values estimated at each point in the spatial domain also are calculated during the kriging process. Areas containing estimated concentration values with elevated standard deviations represent locations where collection of additional information could reduce uncertainties regarding the extent and magnitude of contaminants in the subsurface. Therefore, a monitoring program could be "optimized" by using available information to identify those areas having the greatest associated uncertainty. Conversely, sampling points can be successively eliminated from simulations, and the standard deviations examined, to evaluate if a significant loss of information (represented by elevated standard deviations) occurs as the number of sampling points is reduced. Repeated application of geostatistical estimating techniques, using tentatively identified sampling locations, can then be used to generate a sampling program that would provide an acceptable level of uncertainty regarding chemical distribution with the minimum possible number of samples collected.

The public-domain geostatistical software package GEO-EAS (Englund and Sparks, 1992), developed by USEPA, was used in a screening-level kriging evaluation of sampling uncertainty based on TCE concentrations detected in groundwater samples collected at Site LF014 in April and May 1998. The sample mean and standard deviation and median kriging standard deviation were first calculated using the results for 23 groundwater monitoring wells sampled in April and May 1998. The April/May sampling event was used in this analysis because it was thought to provide the most spatially complete coverage of the site of any single sampling event conducted at Site LF014. Two

of the wells, sampled in April/May 1998, LF014MW003 and LF014MW030 were excluded from this analysis. LF014MW003 was excluded because it is screened in the Navarro Clay, and LF014MW030 was excluded because it is located on the southern bank of Leon Creek (i.e., it is not hydraulically connected to the Site LF014 contaminant plume). The analytical results for samples collected from groundwater RWs also were excluded from the analysis because chemical concentrations in samples from RWs are representative of average conditions within a relatively large volume of the groundwater system (within the capture radius of the well), and are not regarded as representative of conditions at a point in space.

Cross-validation was completed to check the validity of the semivariogram model chosen to represent the complete 1998 data set. The process of cross-validation systematically estimates values for locations with known TCE concentrations by calculating estimates for each well (location) assuming the value for that location is unknown. The estimated TCE concentration for each well location was compared to the measured concentration used in the formation of the semivariogram model, and the mean and standard deviation were used to compare the results. The semivariogram model for Site LF014 was based on the natural logarithm (log) of TCE concentrations. The mean and standard deviation for the known natural log TCE concentrations were 2.83 and 2.56, respectively. The semivariogram model estimated a mean of the natural log TCE concentrations of 2.49 with a standard deviation of 3.57. The mean kriging standard deviation was 1.09.

The cross-validation results indicate that the model slightly underestimates the log TCE concentrations at sampling locations, but that the results are generally comparable. The conclusions that can legitimately be drawn from cross-validation results are limited (Isaaks and Srivastava, 1989), and were used in this screening-level evaluation as a qualitative assessment of the validity of the model. The semivariogram model was then used to calculate estimated log TCE concentrations and associated kriging standard deviations for the entire site. The average median estimated log TCE value was 3.07, and the median kriging standard deviation was 1.16. The log TCE values and median kriging standard deviations were then used as a basis for evaluating the LTM wells.

A screening-level series of kriging calculations was completed that included only the 12 monitoring wells currently sampled as part of the LTM plan. Results of this analysis were compared with the results of the analysis of the more complete 23-well 1998 sampling event to evaluate the amount of information loss (increases in kriging error) resulting from the use of fewer monitoring points. Estimated log TCE concentrations and associated kriging standard deviations were generated for the site using a semivariogram model for the LTM plan wells. This model produced a median estimated log TCE value of 2.92 compared to 3.07 for the more complete (1998) data set. The median estimated kriging standard deviation produced by the semivariogram model for the LTM plan wells was 1.53, compared to 1.16 generated for the more complete data set. Comparison of the models indicates that decreasing the number of wells sampled from 23 to 12 increased the uncertainty of the estimate, or kriging standard deviation, from 1.16 to 1.53. The regions of greatest uncertainty occur within the rectangle formed by wells LF014MW009, LF014MW012, LF014MW004, and LF014MW026, and between LF014MW027 and LF014MW004. The increase in uncertainty of the estimates indicates that the distribution of LTM wells may not be sufficient to accurately evaluate the spatial distribution of contaminants across the entire site.

If additional spatial characterization of contaminants at Site LF014 is desired in the future, geostatistics could be used to design a sampling plan that would provide an acceptable degree of uncertainty in the estimated contaminant distribution and magnitude. Using the semivariogram model that was developed for the 1998 sampling event, wells that provide redundant information could be identified and eliminated from the LTM program. Future sampling events intended to provide information regarding the spatial distribution of contaminants at the site may be designed with an equivalent or lower uncertainty (kriging standard deviation) than the 1998 sampling event with fewer wells sampled.

### 6.3 QUALITATIVE ANALYSIS

The wells selected for LTM also can be evaluated on a qualitative basis considering the hydrogeologic conditions at the site and the temporal contaminant concentration trends at individual wells. Sampling of wells LF014MW005, LF014MW012, and LF014MW003 currently is required by the Base Compliance Plan (TNRCC, 1998). These wells are located downgradient from the Site LF014 disposal areas along the northern bank of Leon Creek (Figure 6.1). Wells LF014MW005 and LF014MW012 provide an indication of contaminant concentrations that are discharging to Leon Creek. LF014MW003 is screened in the upper 10 feet of the Navarro Clay, and is therefore not representative of the surficial aquifer. There are no POC wells screened in the surficial aquifer in the 600-foot-long area between LF014MW012 and LF014MW026. Based on the discussion of potential source area locations in Section 3.4, one appropriate location for an additional surficial aquifer POC well may be near Leon Creek between LF014MW003 and LF014MW012. A monitoring well in this area would be hydraulically downgradient from the magnetic anomalies detected near LF014MW009 and from areas of elevated total CAH concentrations in groundwater.

Monitoring wells LF014MW030 and LF013MW005, located south of the creek upstream and downstream from the Leon Creek dam, respectively (Figure 6.1), also are sampled as part of the Basewide LTM program. These wells are most likely hydraulically disconnected from the contaminant plume at Site LF014. The detection of chlorobenzene in groundwater at LF014MW030 at concentrations of 180 to 200 µg/L in 1996 and 1997 suggests that contamination at this location does not originate at Site LF014. However, monitoring of this well provides potentially useful information regarding contaminant discharge to Leon Creek from other adjacent sites.

Wells LF014MW026, LF014MW004, and LF014MW027 are located southeast of (crossgradient from) the groundwater recovery system. Concentrations of CAHs in these wells have been below groundwater quality standards since they were initially sampled in 1990. However, concentrations of metals and the SVOC bis(2-ethylhexyl)phthalate above groundwater quality standards have been detected in wells LF014MW004 and LF014MW027, respectively. There have not been any exceedances of groundwater quality standards for VOCs, SVOCs, or metals at LF014MW026. Significant increases in contaminant concentrations at these wells would signal changing conditions at the site.

Wells LF014MW028, LF014MW006, and LF014MW009, located in the interior of the landfill (Figure 6.1), have exhibited concentrations of total CAHs that significantly exceed RGs. These wells are located upgradient from the groundwater extraction wells, and provide information about contaminant concentrations in source areas.

## 6.4 CONCLUSIONS AND RECOMENDATIONS

Recommendations for future LTM at the site are based on the current hydrogeologic conditions. The LTM plan should be reassessed if site conditions change in the future. Recommendations for refinement of the LTM plan are contained in the following subsections.

### 6.4.1 Wells Recommended For Monitoring

- LF014MW026 and LF014MW027: these crossgradient wells (Figure 6.1) have not been significantly contaminated in the past; however, their continued monitoring is recommended to ensure that significant contaminant concentrations are not migrating from the southeastern portion of the landfill.
- LF014MW004: this well is located northeast of (upgradient from) the landfill and appears to be properly situated to monitor background groundwater quality. Continued monitoring of this well is not recommended unless significant contaminant concentrations are detected at LF014MW026.
- LF014MW030 and LF013MW005: These wells are potentially useful indicators of mass loading to Leon Creek from other sources southwest of the creek (Figure 6.1). Continued monitoring is recommended as long as contaminant concentrations are present in these wells that could impact surface water quality in the creek.
- LF014MW005 and LF014MW012: These wells are useful POC wells indicating the degree of contaminant discharge to Leon Creek from Site LF014; continued monitoring is recommended.
- LF014MW003: This well is screened in the low permeability Navarro Clay, and monitoring should be discontinued. Installation and monitoring of a new well near the creek approximately 100 feet upstream (downgradient from LF014MW077) is recommended instead. A groundwater sample collected from well LF014MW077 in 1998 contained 150 µg/L of TCE and the highest total chromium and selenium concentrations detected during that sampling event. These data suggest that this well may be located along a contaminant migration pathway between the north-central magnetic anomaly, which potentially represents a significant source area, and the creek.
- LF014MW009: Continue to monitor to assess temporal concentration trends and natural attenuation of CAHs. This well is located near the north-central magnetic anomalies depicted on Figure 3.5, and groundwater samples from this well should be indicative of temporal changes in the strength of this potentially significant source.
- LF014MW028: Assuming that the purpose of monitoring this well is to assess temporal changes in contaminant concentrations within the landfill, substitution of LF014MW086 should be considered. This well is located approximately 130 feet east of LF014MW028, and had higher total CAH and metal concentrations in 1998.

- LF014MW006: Assuming that the purpose of monitoring this well is to assess temporal changes in contaminant concentrations within the landfill, substitution of LF014MW085 is recommended. This well is located approximately 170 feet northeast of LF014MW006, and substantially elevated total CAH concentrations (e.g., TCE = 90,000 µg/L) were detected at this location in 1998. In addition, the 1998 groundwater sample from this well contained elevated metals concentrations (especially chromium). This well is located adjacent to the northeast magnetic anomaly, which may represent a potentially significant source area.
- SS035MW010: Groundwater from this background well (Figure 6.1) has contained CAH contamination in the past; however, the contamination may be attributable to another source upgradient from the landfill. Continued monitoring of this well is recommended to help delineate site-related contamination relative to contamination sourced farther upgradient.
- LF014MW075 and LF014MW078: These wells had substantially elevated total lead concentrations in 1998 (1,400 µg/L and 16,500 µg/L, respectively). Resampling of these wells for lead (total and dissolved) is recommended. If lead concentrations remain elevated, then periodic monitoring of these wells for lead should be considered.

#### **6.4.2 Target Analytes**

Historical information (Section 1.3) indicates that pesticides were disposed of at the landfill. However, to date there has been only a single trace detection of one pesticide compound (*alpha*-Endosulfan, 0.0066J µg/L) in site groundwater. PCBs have not been detected in site groundwater. Therefore, analysis for these parameters should be either reduced or eliminated. These analytes could be targeted at selected POC and corrective-action observation wells on biennial (every-other-year) basis.

All other parameters currently analyzed during LTM of site wells should continue to be included in the LTM analytical protocol. Metals data should include analyses for total and dissolved fractions, and concentrations of both hexavalent and trivalent chromium should be assessed.

## SECTION 7

### RECOMMENDATIONS

Based on the reviews provided in Sections 3 through 6, the following recommendations are made to refine future remediation plans for Site LF014 at Kelly AFB.

Recommendation No. 1: Periodically reassess the decision to follow either the old regulatory framework (RRR) or the new TRRP. Based on information presented in Section 4, the long-term benefits of the TRRP may outweigh the temporary inconvenience and cost of switching rules.

*Rationale: The BRA completed for Site LF014 may require revision under the RRR, whereas a BRA is not required under the TRRP. If it is assumed that Site LF014 groundwater could be used as drinking water, RRR cleanup levels need to be achieved throughout the plume. In contrast, the TRRP provides the option to control and manage the COCs without active remediation through the use of a plume-management zone. In addition, the TRRP provides clear guidance on the use of a dilution factor when assessing groundwater discharge to surface water. Target risk levels specified in the TRRP are less conservative than the risk levels specified under the RRR.*

Recommendation No. 2: Analyze groundwater samples from selected wells for dissolved metals and for both hexavalent and trivalent chromium to determine the proper regulatory standards to use as the basis for metals RGs.

*Rationale: Assessment of dissolved metal concentrations will enable more direct comparison of groundwater quality data to TWQS' for surface water. This comparison will facilitate assessment of the portion of the site groundwater that would require containment to prevent discharge to Leon Creek, and refinement of the required extraction trench length. The TWQS for hexavalent chromium is significantly lower than that for trivalent chromium.*

Recommendation No. 3: Perform a detailed assessment of groundwater flow velocities within the gravel zone along the proposed trench installation line, and of the rate at which contaminated groundwater discharges to Leon Creek in the plume area. This assessment could be accomplished by performing additional aquifer permeability tests and by calibrating a numerical model of the site to the detailed groundwater surface depicted on Figure 3.4. The numerical model calibrated by SAIC (1998) could be used as the basis for this activity.

Rationale: *Assessing the impact of dilution on contaminants discharging to the creek could lead to a reduction in the required length of a plume intercept trench; lower concentrations near the plume periphery may not require capture/treatment. In addition, the required thickness (and cost) of a PRB is directly proportional to the groundwater velocity.*

Recommendation No. 4: Resample well LF014MW085 to confirm the substantially elevated contaminant concentrations detected during the 1999 sampling. If the elevated concentrations are confirmed, consider engineered addition of substrate (e.g., vegetable oil) to enhance the reductive dechlorination of the chlorinated solvents.

Rationale: *The CAH concentrations detected at this well are orders of magnitude higher than detected at any other sampling location. The Base should be aware of the maximum CAH concentrations present in the groundwater for remedial design purposes. Addition of substrate would promote relatively rapid reduction of chlorinated solvent concentrations in “hotspot” groundwater.*

Recommendation No. 5: If the Base decides to continue site cleanup under the RRR, a site-to-background comparison should be performed for metals, and statistical comparisons between site concentrations and preliminary cleanup levels should be conducted per USEPA (1989 and 1992) guidance and consistent with 30 TAC 335.553(d)(3).

Rationale: *These activities could significantly reduce the list of final metals COCs.*

Recommendation No. 6: If the Base decides to continue under the RRR, pursue regulatory acceptance of a future land use other than residential (see Section 4.1.2).

Rationale: *RGs proposed to date are based on the assumption that all groundwater at and downgradient from Site LF014 represents a potential drinking water source. However, COCs and their associated RGs in groundwater may be modified if it is documented to the agency’s satisfaction that a future land use other than residential is appropriate for the site, and institutional or legal controls will effectively prevent use of contaminated groundwater (30 TAC 335.563(h)). Under this option, current and reasonably expected future exposure routes would need to be considered in the RRR Standard 3 BRA, and alternate concentration limits would need to be calculated per 30 TAC 335.160(b).*

Recommendation No. 7: If the remedial schedule permits, perform a detailed assessment (i.e., conceptual design) of the width and cost of a permeable reactive barrier (i.e., iron filings wall) prior to making a final decision regarding the groundwater remedy.

Rationale: *Remedial alternative 2 (iron filings wall) may achieve the objective of protecting of Leon Creek from discharge of contaminated groundwater at the lowest overall long-term cost under the following scenario:*

- *if the outcome of recommendation number 3 indicates that the trench could be narrower than was assumed for costing purposes;*
- *if treatment of groundwater to drinking water levels is not required; and/or*

- *if groundwater extraction at other Zone 1 sites also ceased, precluding the necessity of constructing a new GWTP for flow from Zone 1*

*Note that a much smaller extraction/treatment trench may be adequate because dilution calculations and actual stream sampling may show that surface water criteria are exceeded by a relatively small portion of the landfill leachate. The source of VOC contamination in the southeastern portion of the landfill appears to be decreasing, and concentrations of TCE are relatively low. The ongoing benefits of natural attenuation should be considered when determining the need for groundwater extraction in the southern portion of the landfill.*

Recommendation No. 8: Regrading and revegetation of the landfill to minimize infiltration of recharge water may prolong the required duration of groundwater collection/treatment. If landfill leachate is being controlled (e.g., via an extraction trench), then infiltration that flushes contaminants out of the source area and into the groundwater is desirable to deplete the contaminant sources more rapidly. At a minimum, exploratory trenching should be performed in the northeast and north-central magnetic anomaly areas (Figure 3.5) to assess the presence of solvent source materials (e.g., drums) that could be relatively easily removed. A decision to more completely excavate these areas should be made following exploratory trenching.

*Rationale: Flushing of contaminants from the vadose zone into the groundwater, and excavation of buried wastes, will reduce future OM&M costs and accelerate site closure.*

Recommendation No. 9: Consider these recommendations during the reevaluation of groundwater remedial alternative OU1-14 described in Section 1.4.5.

Recommendation No. 10: Implement the monitoring-related recommendations outlined in Section 6.

## SECTION 8

### REFERENCES

- American Society of Civil Engineers (ASCE) Task Committee on Geostatistical Techniques in Hydrology. 1990a. Review of Geostatistics in Geohydrology—I. Basic Concepts. *Journal of Hydraulic Engineering* 116(5):612-632.
- ASCE Task Committee on Geostatistical Techniques in Hydrology. 1990b. Review of Geostatistics in Geohydrology—II. Applications. *Journal of Hydraulic Engineering* 116(5):633-658.
- Bouwer, E.J. 1994. Bioremediation of chlorinated solvents using alternate electron acceptors. In *Handbook of Bioremediation*: Lewis Publishers, Norris, R.K., Hinchee, R.E., Brown, R., McCarty, P.L, Semprini, L. Wilson, J.T., Kampbell, D.H., Reinhard, M., Bouwer, E.J., Borden, R.C., Vogel, T.M., Thomas, J.M., and Ward, C.H., eds. 149-175.
- Butler, B.J., and Barker, J.F. 1996. Chemical and microbiological transformation and degradation of chlorinated solvent compounds. In *Dense Chlorinated Solvents and Other DNAPLS in Groundwater: History, Behavior, and Remediation*, Pankow, J.F., and Cherry, J.A., eds., Waterloo Press, Waterloo, Ontario: 267-312.
- Bradley, P.M., and Chapelle, F.H. 1996. Anaerobic mineralization of vinyl chloride in Fe(III)-reducing aquifer sediments: *Environmental Science and Technology*, 40:2084-2086.
- Bradley, P.M., Chapelle, F.H., and Lovley, D.R. 1998. Humic Acids as Electron Acceptors for Anaerobic Microbial Oxidation of Vinyl Chloride and Dichloroethene: *Applied and Environmental Microbiology*, 64(8): 3102-3105.
- CH2M Hill. 1999a. *January 1999 Semiannual Compliance Plan Report*. January.
- CH2M Hill. 1999b. *Final Quality Assurance Project Plan*. June.
- CH2M Hill. 1999c. *Final Sampling and Analysis Plan*. June.
- CH2M Hill. 1999d. *Draft Zone 1 Soils Corrective Measure Study*. April.
- CH2M Hill. 1999e. *January 2000 Semiannual Compliance Plan Report*. November.
- Clark, I. 1987. *Practical Geostatistics*: Elsevier Applied Science, Inc. London.
- Davis, J.W., and Carpenter, C.L. 1990. Aerobic biodegradation of vinyl chloride in groundwater samples: *Applied and Environmental Microbiology*. 56:3878.

- DeBruin, W.P., Kotterman, M.J.J., Posthumus, M.A., Schraa, G., and Zehnder, A.J.B. 1992. Complete biological reductive transformation of tetrachloroethene to ethane: *Applied and Environmental Microbiology*, 58(6): 1966-2000.
- DeStefano, T.D., Gossett, J.M., and Zinder, S.H. 1991. Reductive dehalogenation of high concentrations of tetrachloroethene to ethene by an anaerobic enrichment culture in the absence of methanogenesis: *Applied and Environmental Microbiology*, 57(8): 2287-2292.
- Engineering-Science, Inc. (ES). 1982. *Installation Restoration Program, Phase I - Records Search, Kelly AFB, Texas*.
- Englund, E., and A. Sparks. 1992. *GEO-EAS (GEOstatistical Environmental Assessment Software), Program Version 1.2.1 and User's Guide*. U.S. Environmental Protection Agency (USEPA). EPA/600/4-88/033a.
- Freedman, D.L., and Gosset, J.M. 1989. *Biological reductive dehalogenation of tetrachloroethylene and trichloroethylene to ethylene under methanogenic conditions*. *Applied and Environmental Microbiology*. 55(4): 1009-1014.
- Halliburton NUS Environmental Corporation (HNUS). 1992a. *Remedial Investigation Report, Groundwater Zone 1*. November.
- HNUS. 1992b. *Final Focused Feasibility Study For Groundwater Contamination, Site LF014*. August.
- HNUS. 1992c. *Leon Creek Surface Water Quality at Kelly Air Force Base, Kelly Air Force Base*.
- HNUS. 1996. *Feasibility Study for Zone 1 Groundwater, Final*. March.
- HydroGeoLogic, Inc. 1999. *Draft Final Basewide Ground-water Flow Model for Kelly AFB, Texas*.
- Isaaks, E.H., and R.H. Srivastava. 1989, *Applied Geostatistics*. Oxford University Press. New York.
- Klier, N.J., West, R.J., and Donberg, P.A. 1996. Aerobic Biodegradation of Dichloroethylenes in Surface and Subsurface Soils. Accepted for publication in *Chemosphere*.
- McCarty, P.L., and Semprini, L. 1994. Ground-Water Treatment for Chlorinated Solvents, In: *Handbook of Bioremediation*. Lewis Publishers, Boca Raton, FL. 1994.
- Murray, W.D. and Richardson, M. 1993. Progress toward the biological treatment of C<sub>1</sub> and C<sub>2</sub> halogenated hydrocarbons: *Critical Reviews in Environmental Science and Technology*. 23(3): 195-217.
- O'Brien, Captain. 2000. Personal communication, Kelly AFB. May.
- Parsons Engineering Science, Inc. (Parsons ES). 1998. *Final Program Health and Safety Plan for Remedial Process Optimization (RPO)*. December.

- Parsons ES. 1999a. *Draft Remedial Process Optimization Handbook*. June.
- Parsons ES. 1999b. *Work Plan for Remedial Process Optimization*. October.
- Powell, R.M. and R.W. Puls. 1997. "Permeable Reactive Subsurface Barriers for the Interception and Remediation of Chlorinated Hydrocarbon and Chromium (VI) Plumes in Ground Water." *USEPA Remedial Technology Fact Sheet*. EPA/600/F-97/008.
- Powell, R.M. and Powell, P.D. 1998. "Iron Metal for Subsurface Remediation." *The Encyclopedia of Environmental Analysis and Remediation*. Robert A. Myers, ed. John Wiley & Sons, Inc., New York. 8:4729-4761.
- Radian Corporation. 1984. *Installation Restoration Program, Phase II, Stage 1 Field Evaluation, Final Report, Kelly AFB, Texas*.
- Radian Corporation. 1988. *Installation Restoration Program, Phase II Confirmation/Quantification Stage 2, Volume I - Text*.
- Rock, N.M.S. 1988. *Numerical Geology*. Springer-Verlag. New York.
- Science Applications International Corporation (SAIC). 1998. *Basewide Operation and Maintenance, Interim Groundwater Recovery System Evaluation Report*.
- Texas Natural Resource Conservation Commission (TNRCC). 1993. *Industrial Solid Waste and Municipal Hazardous Waste, Chapter 335, Subchapter S, Risk Reduction Standards*.
- TNRCC. 1998. *Compliance Plan for Industrial Solid Waste Management Site, CP-50310*. June.
- TNRCC. 1999. *Texas Risk Reduction Program Rule, Chapter 350, Risk Reduction Standards*.
- U.S. Environmental Protection Agency (USEPA). 1989. *Risk Assessment Guidance to Superfund, Volume 1 – Human Health Evaluation Manual (Part A)*. Interim Final. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-89/002.
- USEPA. 1992. *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, OSWER Directive 9283.1-06.
- USEPA. 1993. *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration*. EPA/540-R-93-080. September.
- USEPA. 1996. *National Primary Drinking Water Regulations*.
- USEPA. 1998. *Technical Protocol for Evaluation Natural Attenuation of Chlorinated Solvents in Groundwater*. EPA/600/R-98/128. September.
- Vogel, T.M., and McCarty, P.L. 1985. Biotransformation of tetrachloroethylene to trichloroethylene, dichloroethylene, vinyl chloride, and carbon dioxide under

methanogenic conditions: *Applied and Environmental Microbiology*, 49(5): 1080–1083.

Vogel, T.M., Criddle, C.S., and McCarty, P.L. 1987. Transformations of Halogenated Aliphatic Compounds. *Environmental Science and Technology*. 21(8):722-736.

Vogel, T.M. 1994. Natural Bioremediation of Chlorinated Solvents, In: *Handbook of Bioremediation*. Lewis Publishers, Boca Raton, FL. 1994.

Weston. 1995. *Interim Groundwater Remedial System for Zones 1 and 2, Kelly AFB, San Antonio Texas*. May.

**APPENDIX A**  
**CALCULATION OF ALTERNATIVE, RISK-BASED CLEANUP**  
**STANDARDS**

**CALCULATION OF SCREENING LEVEL PRELIMINARY REMEDIATION GOALS - GROUNDWATER <sup>a/</sup>  
INTRUSIVE INDUSTRIAL WORKER - RME SCENARIO  
KELLY RPO**

Exposure Assumptions	DA <sub>event</sub> Equations
Receptor	Groundskeeper: RME Scenario Carcinogenic:
Dose absorbed per unit area per event (DA <sub>event</sub> )	chemical-specific mg/cm <sup>2</sup> -event <sup>a/</sup>
Target cancer risk level (TR)	1.00E-06 unitless
Body Weight (BW)	70 kg
Averaging Time, Carcinogens (AT <sub>c</sub> )	70 yrs
Dermal Slope Factor (SF <sub>d</sub> ) (i.e., SF <sub>o</sub> adjusted for GI absorption)	chemical-specific (mg/kg-day) <sup>-1</sup> <sup>b/</sup> where $SF_d = \frac{(SF_o)}{(OAF)}$ and: OAF = Oral GI absorption factor (chemical-specific; unitless)
Exposure Frequency (EF)	50 days/yr <sup>c/</sup>
Exposure Duration (ED)	1 yr
Event Frequency (EV)	1 events/day
Fraction of Estimated Time in Contact with Water (EC)	1 unitless
Exposed Body Surface Area (SA)	4450 cm <sup>2</sup>
Target hazard quotient (THQ)	1 unitless
Dermal Reference Dose (RfD <sub>d</sub> ) (i.e., RfD <sub>o</sub> adjusted for GI absorption)	chemical-specific mg/kg-day      where $RfD_d = (RfD_o)(OAF)$
Averaging Time, Noncarcinogens (AT <sub>nc</sub> )	1 yr
	Noncarcinogenic: $DAevent_{nc} = \frac{(THQ)(BW)(RfD_d)(AT_{nc})(365day/year)}{(EF)(ED)(EV)(EC)(SA)}$

Contaminant	CAS Number <sup>d/</sup>	SF <sub>o</sub> (mg/kg-day) <sup>-1</sup>	RfD <sub>o</sub> (mg/kg-day)	OAF (unitless)	SF <sub>d</sub> (mg/kg-day) <sup>-1</sup>	RfD <sub>d</sub> (mg/kg-day)	DAevent <sub>carc</sub> (mg/cm <sup>2</sup> -event)	DAevent <sub>nc</sub> (mg/cm <sup>2</sup> -event)	DAevent (mg/cm <sup>2</sup> -event)	COPC Classification for DAevent <sup>d/</sup>
<b>Volatile Organic Compounds</b>										
Trichloroethene	79-01-6	1.10E-02	6.00E-03	1.00E+00	1.10E-02	6.00E-03	7.31E-04	6.89E-04	6.89E-04	NC

<sup>a/</sup> mg/cm<sup>2</sup> = milligram per square centimeter.

<sup>b/</sup> mg/kg-day = milligram per kilogram-day

<sup>c/</sup> days/yr = days per year

<sup>d/</sup> CAS = Chemical Abstracts Service number.

<sup>e/</sup> -- = toxicity data not available.

**CALCULATION OF SCREENING LEVEL PRELIMINARY REMEDIATION GOALS - GROUNDWATER <sup>a/</sup>  
INTRUSIVE INDUSTRIAL WORKER - RME SCENARIO  
KELLY RPO**

Input Parameters			PRG Equations	
Receptor	Groundskeeper: RME Scenario		For inorganics:	
Site-specific preliminary remediation goal based on dermal contact with groundwater (PRG <sub>derm</sub> )	chemical-specific	μg/L <sup>a/</sup>	$PRG_{derm-inorg} = \frac{(DA_{event})(CF)}{(K_p)(t_{event})}$	
Dose absorbed per unit area per event (DA <sub>event</sub> )	chemical-specific	mg/cm <sup>2</sup> -event <sup>b/</sup>		
Conversion Factor (CF)	1.00E+06	(ml/L) x (μg/mg) <sup>c/</sup>	For organics:	
Permeability coefficient from water (K <sub>p</sub> )	Chemical-specific	cm/hr <sup>d/</sup>		
Duration of event (t <sub>event</sub> )	0.5	hr/event <sup>e/</sup>	If t <sub>event</sub> < t*, then: $PRG_{derm-org} = \frac{(DA_{event})(CF)}{2K_p \sqrt{\frac{6t_{event} t_{event}}{p}}}$	
Time it takes to reach steady state (t*)	Chemical-specific	hr/event		
Lag time per event (t <sub>event</sub> )	Chemical-specific	hr/event	If t <sub>event</sub> > t*, then: $PRG_{derm-org} = \frac{(DA_{event})(CF)}{K_p \left[ \frac{t_{event}}{1+B} + 2t_{event} \left( \frac{1+3B+3B^2}{(1+B)^2} \right) \right]}$	
Relative contribution of permeability coefficients in stratum corneum and viable epidermis (B)	Chemical-specific	unitless		

Contaminant	Type <sup>f/</sup>	K <sub>p</sub> (cm/hr)	t* (hr/event)	t <sub>event</sub> (hr/event)	B (unitless)	DA <sub>event</sub> (mg/cm <sup>2</sup> -event)	PRG <sub>derm-inorg</sub> (μg/L)	PRG <sub>derm-organic</sub> (μg/L)	PRG <sub>derm</sub> (μg/L)	COPC Classification for PRG <sub>derm</sub> <sup>a/</sup>
<b>Volatile Organic Compounds</b>										
Trichloroethene	o	1.60E-02	1.30E+00	5.50E-01	2.60E-02	6.89E-04		2.66E+04	2.66E+04	NC

<sup>a/</sup> μg/L = micrograms per liter

<sup>b/</sup> mg/cm<sup>2</sup>-event = milligrams per centimeter-event

<sup>c/</sup> (ml/L) x (μg/mg) = milliliter per liter times microgram per milligram

<sup>d/</sup> cm/hr = centimeters per hour

<sup>e/</sup> hr/event = hours per event

<sup>f/</sup> "o" indicates an organic compound, "i" indicates an inorganic compound



23 March 2000

John Hicks  
Parsons Engineering Science, Inc.  
1700 Broadway, Suite 900  
Denver, CO 80290

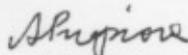
**Reference:** *In-Situ Application of the EnviroMetal Process at site D-4, Kelly AFB, San Antonio, TX - 31729.88*

Dear Mr. Hicks:

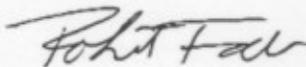
Thank you for your interest in using the EnviroMetal Process for remediation of contaminated groundwater at site D-4, Kelly AFB, San Antonio, TX. We believe the iron technology has the potential to provide a cost-effective remedy for treatment of the chlorinated VOCs identified in groundwater at the site. Attached are our initial recommendations regarding technology application. We would be happy to visit your company and provide your group with an update of our technology, as well as discuss your site in more detail. In the meantime, if you have any questions concerning the following cost estimate, please contact us.

Sincerely,

**EnviroMetal Technologies Inc.**

A handwritten signature in cursive script, appearing to read "A. Przepiora".

Andrzej Przepiora, M.Sc.  
Hydrogeologist

A handwritten signature in cursive script, appearing to read "Rob Foch".

Rob Foch, P.Eng., M.Sc.  
Remediation Engineer

Encl.



***IN-SITU* APPLICATION OF THE ENVIROMETAL PROCESS AT  
SITE D-4, KELLY AFB, SAN ANTONIO, TX**

Prepared For:

**Parsons Engineering Science, Inc.**  
1700 Broadway, Suite 900  
Denver, CO 80290

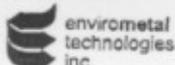
Prepared By:

**EnviroMetal Technologies Inc.**  
745 Bridge St. West, Suite 7  
Waterloo, Ontario  
Canada N2V 2G6

ETI Reference: 31729.88

21 March 2000

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## 1.0 INTRODUCTION

EnviroMetal Technologies Inc. (ETI) received water quality data and hydrogeologic information concerning a contaminated site at site D-4, Kelly AFB, San Antonio, TX on 20 March 2000. From our initial review of the data, we are confident that the EnviroMetal Process (metal enhanced reductive dehalogenation) will degrade the trichloroethene (TCE), cis 1,2-dichloroethene (cDCE) and vinyl chloride (VC) present in the site groundwater to non-toxic materials. The EnviroMetal Process has been successfully applied at several sites where these chlorinated volatile organic compounds (VOCs) are the primary contaminants of concern. To date the technology has not degraded acetone and cis (2-ethylhexyl) phthalate. If these compounds are of concern, combining the EnviroMetal Process with other *in-situ* treatment technologies could be investigated. The iron technology has also been used at a few sites for removal of metals such as hexavalent chromium.

Since 1994, forty-eight permeable walls containing granular iron have been installed to remediate VOCs. There are currently 31 full-scale *in-situ* systems removing VOCs from groundwater, in addition to 17 pilot scale systems, which have been installed to provide "proof of concept" data and more recently to demonstrate innovative construction methods.

Using data from these sites, we have prepared a preliminary cost estimate for an *in-situ* treatment system at the site. If groundwater flow velocities are potentially as fast as listed in your correspondence, hydraulic manipulation/control to limit groundwater flux as a means of reducing overall treatment cost could be discussed. For example, a collection trench or cut-off wall system upgradient of the contaminated area could be installed to divert groundwater away/around the source zone area. Such a system could reduce the amount of groundwater being contaminated, resulting in a decrease in dimensions and cost of the iron treatment zone. Further information regarding above-ground structures, buried utilities and the lateral and vertical extent of the contaminated zones would be required in order to refine this cost estimate.

### 1.1 Site Design Parameters

Several design parameters need to be addressed and quantified in order to apply the EnviroMetal Process in the field, and to determine its cost-competitiveness with other treatment technologies:



- *The dimension of the required in-situ treatment zones.* These dimensions are based on the identity and concentrations of VOCs, degradation rates, groundwater flow rate/velocity, and the plume dimensions.
- *The geotechnical and hydraulic conditions.* These conditions will influence whether the system configuration should be a funnel and gate or continuous permeable wall and will also influence the construction methods used to install the treatment zones. For example, the integrity of a confining layer may influence the choice of system configuration. The presence of buried services along the line of installation could influence the construction method selected.
- *The location of the wall with respect to potential natural attenuation and/or need for treatment of VOCs remaining downgradient*

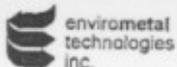
In Section 3.0, we have outlined possible costs associated with an *in-situ* permeable wall installation at the site. A more accurate cost estimate will require quantification of the above design parameters.

## 2.0 RECOMMENDED APPROACH

Our recommended approach to implementing the EnviroMetal Process at a particular site normally involves the following phases:

- Phase I: Data Review
- Phase II: Bench-Scale Testing (If Required)
- Phase III: Assistance with Field Design and Implementation
- Phase IV: Performance Monitoring

However, if the site water entering the iron treatment zone has VOCs with relatively low concentrations and metals are not of concern at the site, Phase II can possibly be omitted. In these cases, degradation rates from ETI's database would be used to design the field-scale treatment system (along with appropriate safety factors). Bench-scale testing would only be performed on the site water if it demonstrated variable inorganic chemistry or the chosen construction method included the use of biodegradable slurry. The necessity of a bench-scale study would be investigated during Phase I. The feasibility and cost of the process at a



particular site is evaluated in detail during the initial phases, which are described in more detail below.

## 2.1 Phase I: Data Review

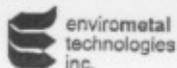
The purpose of this phase is to review available site hydrogeologic, geochemical and geotechnical data as related to the application of the EnviroMetal Process. The concentration and distribution of organic compounds, inorganic groundwater chemistry and the hydrogeology of the site are examined to determine the feasibility and possible treatment zone configurations. When considering *in-situ* treatment, particular attention is given to:

- depth and fluctuations of the water table
- depth to the top and bottom of the contaminated zone
- spatial variation in VOC concentration along the line of installation
- lateral boundaries of the contaminated zone
- flow direction
- groundwater velocity
- hydraulic conductivity
- geotechnical data as they pertain to "constructability" issues

If desired, the data review can be accompanied by a site visit and meeting, in order to obtain additional information regarding site characteristics, possible construction constraints and regulatory requirements. We could also discuss the use of groundwater modeling to facilitate design of the field-scale treatment system (e.g., the use and effect of a groundwater diversion system to limit the groundwater flow rates through the contaminated area). A presentation regarding the technology could also be made at this time to the involved parties. We have found that a site visit greatly facilitates project communication and co-ordination. A cost estimate for Phase I is given in Table 1.

## 2.2 Phase II: Bench-Scale Testing (If Required)

Phase II involves laboratory column tests using groundwater from the site and commercial granular iron material. These tests enable us to predict system performance and provide data for field design. Note that the test could be expanded to investigate the use of biodegradable



slurry, if deemed appropriate. The bench-scale testing can be conducted at the University of Waterloo, Waterloo, Ontario under contract to ETI.

The laboratory column tests establish site-specific VOC degradation rates under flowing conditions. These rates are used to determine the required residence time in the reactive material. Using the residence time and the flow rate, the size of the treatment zone is determined. The laboratory column tests also include inorganic sampling of column influent and effluent. This provides information concerning potential mineral precipitation in the reactive material caused by changing redox potential (Eh) and pH conditions. The potential for mineral precipitation must be considered in the field design.

The standard laboratory protocols and measurement methods used to test the site groundwater are designed to provide high quality data at minimal cost. The column is made of Plexiglas™ with an inner diameter of 1.5 in and a length of either 1.6 or 3.3 ft (Figure 1). Groundwater from the site is supplied to the influent end of the column at a constant flow velocity using a laboratory pump. The flow velocity is selected to approximate the velocity expected in a field-scale treatment zone. This flow velocity is determined through consultation with the client. VOC concentrations are measured along the column until a steady-state profile is achieved. Eh and pH profiles are measured periodically during the test. Inorganic parameters (major cations, anions, and alkalinity) are monitored to help predict possible mineral precipitation. If necessary, other chemical parameters relevant to a particular site and/or proposed construction method can also be measured.

The water shipped to the laboratory from the site should have characteristics (VOC concentrations and inorganic chemistry) similar to the groundwater expected to enter a field-scale treatment system. Shipping instructions are provided by ETI once the project proceeds.

Test co-ordination, column testing and reporting will cost approximately \$15,000. This cost will increase by an additional \$5,000 if sampling and determination of metal removal rates is required. The report issued at the conclusion of the laboratory tests will include:

- results of all chemical analyses
- calculated degradation rates
- summary tables of major results
- graphs showing degradation profiles



Estimated residence time requirements for the field application will also be calculated, based on laboratory results and VOC design influent concentrations and effluent maximum contaminant levels (MCLs).

### 2.3 Phase III: Assistance with Field Design and Implementation

ETI's principal role in Phase III is to act as a design consultant to your staff. That is, your organization would have responsibility for the overall program (completion of design documents, obtaining construction permits, general construction oversight and co-ordination, implementation of monitoring program, etc.). ETI would assist in these tasks, and bill on a time and materials basis for this work. Particular tasks that involve ETI staff include:

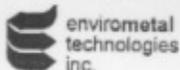
- determination of residence time requirements for VOC treatment
- consultation on system design, in particular, iron treatment zone dimensions
- consultation on system modeling
- assistance in selecting construction method
- specification/procurement/quality assurance of reactive material
- assistance during field installation
- development of a performance monitoring program

We also provide assistance in selecting an installation contractor. Normally, we would recommend choosing a contractor who has experience with iron installations. However, we are prepared to work with other contractors that you or the site owner might select. In certain situations, ETI's involvement in construction aspects of the project is typically greater in order to ensure that quality standards are met.

Site construction management is normally handled by engineering or contracting firms (or, your organization if you provide construction services). ETI retains the right to have on-site representation during the installation phase of the project.

Work on subsequent phases of the design and installation will be billed on a time and materials basis. Once the scope of the project is more fully defined, we can provide cost estimates for these activities. On past projects of this size, our costs have been on the order of about \$10,000 to \$20,000.

ETI has been granted exclusive rights for commercialization of this patented technology by the patent holder, the University of Waterloo. A site license fee of 15% of capital



construction costs is typically charged should full-scale implementation of the technology at the site proceed. However, since this is a DoD facility where multiple installations using the EnviroMetal Process have been completed, a site license fee of 13% will be applied to this site. The fee is based on the cost of delivered iron to the site and the treatment system construction (i.e. cost for the construction of a continuous wall or funnel and gate system installation, including mobilization and demobilization).

#### **2.4 Phase IV: Performance Monitoring**

ETI will assist with the data interpretation and evaluation of system performance over time. This includes preparation and/or review of compliance monitoring documents for submission to the regulatory agencies involved.

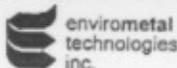
ETI's involvement in performance monitoring will also be billed on a time and materials basis. Because performance monitoring detail and schedules vary from site to site, cost estimates for this phase can be given as the need arises.

### **3.0 ESTIMATED COSTS FOR FULL-SCALE APPLICATION**

The following cost estimate for technology application at the site is presented to provide a degree of insight with respect to the full-scale implementation costs. We emphasize that the costs presented here are based on our experience at other sites, and would need to be refined based on a more complete review of hydrogeologic information and quotations for construction costs. Nevertheless, based on our preliminary review of the data (chlorinated VOCs present and their concentration) we believe these costs will provide a useful guide.

#### **3.1 Capital Costs**

Based on previous laboratory and field results a residence time of about 2 days would be required to reduce the TCE, cDCE and VC detected in the site water at maximum concentrations of 500, 424 and 341  $\mu\text{g/L}$ , respectively, to below the supplied regulatory limits (i.e. TCE = 5  $\mu\text{g/L}$ , cDCE = 70  $\mu\text{g/L}$  and VC = 2  $\mu\text{g/L}$ ). Based on the reported average groundwater flow velocity expected to enter the treatment zone of 1.1 to 3.6 ft/day, an iron zone about 2.2 to 7.2 ft in flow-through thickness will theoretically provide the required residence time.



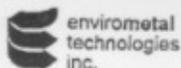
Assuming an iron wall width of about 800 ft and a saturated plume depth of 10 ft, the total volume of iron can be calculated as follows:

$$\begin{aligned}\text{Volume of Iron} &= \text{length of treatment zone} \times \text{saturated height} \times \text{thickness in the direction} \\ &\quad \text{of flow} \\ &= 800 \text{ ft} \times 10 \text{ ft} \times (2.2 \text{ to } 7.2) \text{ ft} \\ &= 17,600 \text{ to } 57,600 \text{ ft}^3\end{aligned}$$

Assuming a bulk density for the iron material of 0.08 ton/ft<sup>3</sup> and a delivered cost of approximately \$400/ton, the cost of about 1,408 to 4,608 ton of iron material may cost on the order of \$560,00 to \$1,840,000. The iron cost could be estimated more accurately if the groundwater flow velocity could be verified with certainty and/or hydraulic control were implemented to limit the amount of groundwater flowing through the contaminated area. The amount of iron placed along the line of installation can also be varied vertically, depending on the flow velocity across different lithological units (e.g., gravel versus clay deposits) in the wall location.

A continuous permeable treatment wall to a depth of about 18 ft could be constructed by a number of methods including continuous trenching and trench box. Due to the limited site geology/geotechnical data provided, it is difficult to determine which construction methods are best suited for the site. Each of the above methods has been used to construct treatment zones containing iron and each has its advantages and disadvantages. The construction methods would be discussed in further detail during Phase I. A brief description and unit costs based on previous projects for these methods are provided below.

Continuous trenching machines have been used for several years to install horizontal groundwater collection drains and impermeable barriers. These machines allow simultaneous excavation and backfilling without an open trench. Excavation is performed by a cutting chain immediately in front of a trench-box (boot) which extends the width and depth of the finished treatment zone. Both the cutting chain and boot are attached to the trenching machine. As the trencher moves forward, iron is added to the boot creating a continuous treatment zone. Trenchers are available to install treatment zones from 1 to 2 ft in width to depths of 25 ft. Cost to construct a permeable wall using this method may be on the order of \$310,00 (one trencher pass for a 2.2 ft wide trench) to 870,000 (four trencher passes to achieve a total trench width of 7.2 ft). This estimate assumes unit cost of \$300/linear ft and \$250/linear ft for the one and four passes, respectively, plus mobilization/ demobilization.



Trench-boxes are used to maintain trench integrity during excavation and backfilling operations. Prefabricated trench-boxes can be quickly setup and placed in a section of trench. For deep trenches, several trench boxes can be stacked and fastened together. After backfilling a section of trench, the treatment zone is advanced by moving the trench-boxes to a new section. The process of consecutively excavating and backfilling continues until the total length of treatment zone is constructed. An estimated cost of installing a continuous iron wall by this method is about \$410,000 to \$480,000 (assumes unit costs of \$25/ft<sup>2</sup> and 30/ft<sup>2</sup> for the 2.2 and 7.2 ft wide trench, respectively, plus mobilization/demobilization).

Table 1 summarizes the installation costs discussed above. Refinement of these costs will depend on more detailed site information. The site license fee for use of the technology is 13% of capital cost (construction labour and delivered iron costs). Costs for activities such as site preparation, permitting, site construction management, etc., which are not included in the above estimate, should also be taken into account.

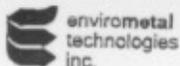
### 3.2 Operation and Maintenance Cost

Other than groundwater monitoring, the major factor affecting O&M costs is the possible need for periodic rejuvenation of iron sections affected by precipitates. The iron material itself should last for several years to decades. The precipitates (if significant) will form in a narrow zone at the upgradient aquifer/iron interface. Rejuvenation therefore could be as simple as agitating the upgradient face of the iron every few (i.e. 7 to 10) years with an auger to restore the permeability of this material.

This periodic O&M requirement should be included in long-term cost models for the technology. We note that no significant precipitates were observed in cores from an *in-situ* reactive wall at an Ontario test site four years after it was installed. This wall performed consistently for over 5 years. There is also no evidence of sliming or plugging in commercial *in-situ* systems operating successfully for over 5 years.

## 4.0 SUMMARY

Based on our review of the data you have provided, the *in-situ* iron technology has the potential to provide a technically feasible method for remediation of the majority of VOCs present at the site. These VOCs have been treated in previous field applications, and the construction depths, etc., are within reasonable limits where the technology can be successfully applied.



**Table 1: Preliminary Cost Estimate for Implementation of the Iron Wall Technology at Site D-4, Kelly AFB, San Antonio, TX**

Phase	Estimated Cost (US\$)
I Data review Site Visit and Meeting <sup>a</sup>	\$1,000 \$3,000
II Bench-Scale Testing <sup>b</sup> (If Required)	\$15,000 - \$20,000
III Assistance with Field Design and Implementation	\$10,000 - \$20,000
IV Installation	
• Iron Material	\$560,000 - \$1,840,000
• Construction <sup>c</sup>	<u>\$310,000 - \$870,000</u>
Subtotal	\$870,000 - \$2,710,000
• Site License Fee (13%)	<u>\$113,000 - \$352,000</u>
<b>TOTAL</b>	<b>\$983,000 - \$3,062,000</b>
V Performance Monitoring	Variable

<sup>a</sup> Includes travel

<sup>b</sup> Costs of sample collection and shipment are not included

<sup>c</sup> Based on cost data from other sites. Would need to be refined based on a more complete review of site data and quotation from construction contractors. Does not include costs for activities such as site preparation, permitting, soil disposal, site construction management, etc.



envirometal  
technologies  
inc.

## Memorandum

**To:** John Hicks, Parsons ES, Fax: 303-831-8208

**From:** Andrzej Przepiora, Rob Focht, EnviroMetal Technologies Inc.

**Date:** 27 March 2000

**Re:** Supplemental cost estimate for *In-Situ* Application of the EnviroMetal Process at Site D-4, Kelly AFB, San Antonio, TX -31729B.88

EnviroMetal Technologies Inc. (ETI) has prepared the following supplementary information on using a permeable reactive barrier (PRB) for remediation of contaminated groundwater at Site D-4, Kelly AFB, San Antonio, TX. The original cost estimate for using the EnviroMetal Process at the site was sent to Parsons ES on 23 March 2000. We have updated our estimate based on the dissolved metal concentration data you have provided.

Based on previous laboratory and field results, we are confident that the reactive permeable wall technology can efficiently treat the contaminated groundwater at Site D-4, Kelly AFB, TX, which contains both VOCs (TCE, cDCE and VC) and dissolved metals (chromium, selenium, cadmium, silver, nickel, zinc and mercury) at concentration provided by Parsons ES. The VOCs, chromium and selenium detected in the site water can be treated by granular iron. To treat the dissolved cadmium, lead, silver, zinc and mercury, another medium (i.e., compost) would be required in a separate treatment zone located upgradient of the iron zone. The mechanism of dissolved metal removal in such a zone is based on biotic sulphate reduction to sulphide and a consequent precipitation of metals as sulphides. To provide sufficient hydraulic conductivity in this zone, compost could be mixed with pea gravel to increase porosity.

Based on a preliminary review of the inorganic composition of the site water, a residence time of about 1 day might be required in the compost/pea gravel zone for the removal of the dissolved metals (i.e., cadmium, lead, silver, zinc and mercury) detected in the site groundwater. The previously determined residence time (2 days) required for VOCs degradation should also be sufficient to remove the chromium and selenium in the iron zone. Note that a laboratory treatability test with site groundwater would be required to determine VOC and metal removal rates and to further specify the residence time requirements in both treatment zones. If application of the sequence treatment was considered for metal treatment,

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Memorandum

the cost of the laboratory test, previously quoted at \$20,000, would be increased to about \$25,000.

The cost of the reactive material in the full scale sequence treatment system includes both the cost of granular iron and the compost/pea gravel mix. Assuming a 1 day residence time, groundwater flow velocity expected to enter the treatment zone of 1.1 to 3.6 ft/day, a treatment zone width of about 800 ft and a saturated plume depth of 10 ft, the total volume of compost/pea gravel can be calculated as follows:

$$\begin{aligned}\text{Volume of Iron} &= \text{length of treatment zone} \times \text{saturated height} \times \text{thickness in the direction} \\ &\quad \text{of flow} \\ &= 800 \text{ ft} \times 10 \text{ ft} \times (1.1 \text{ to } 3.6) \text{ ft} \\ &= 8,800 \text{ to } 28,800 \text{ ft}^3\end{aligned}$$

Assuming a delivered cost of compost/pea gravel (20% mix) of approximately \$2/ft<sup>3</sup>, the cost of the mix may be on the order of \$18,000 to \$58,000. Adding the previously determined cost of iron required for the VOC treatment of \$560,000 to \$1,840,000 gives the total cost of reactive material required in the sequence treatment of about \$578,000 and \$1,898,000.

The additional treatment zone will also increase the cost to construct the system. For the continuous trenching method, additional trencher passes will be required, increasing the previous estimate to \$570,000 (assuming the groundwater velocity of 1.1 ft/d) and \$1,290,000 (assuming the groundwater velocity of 3.6 ft/d). The construction cost of the sequence treatment using the trench box method may not change significantly in relation to the previously quoted value and it is estimated at about \$500,000.

Table 1 summarizes the installation costs discussed above. Refinement of these costs will depend on more detailed site information. The site license fee for use of the technology is 13% of capital cost (construction labour and delivered iron costs). Costs for activities such as site preparation, permitting, site construction management, etc., which are not included in the above estimate, should also be taken into account.

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Memorandum

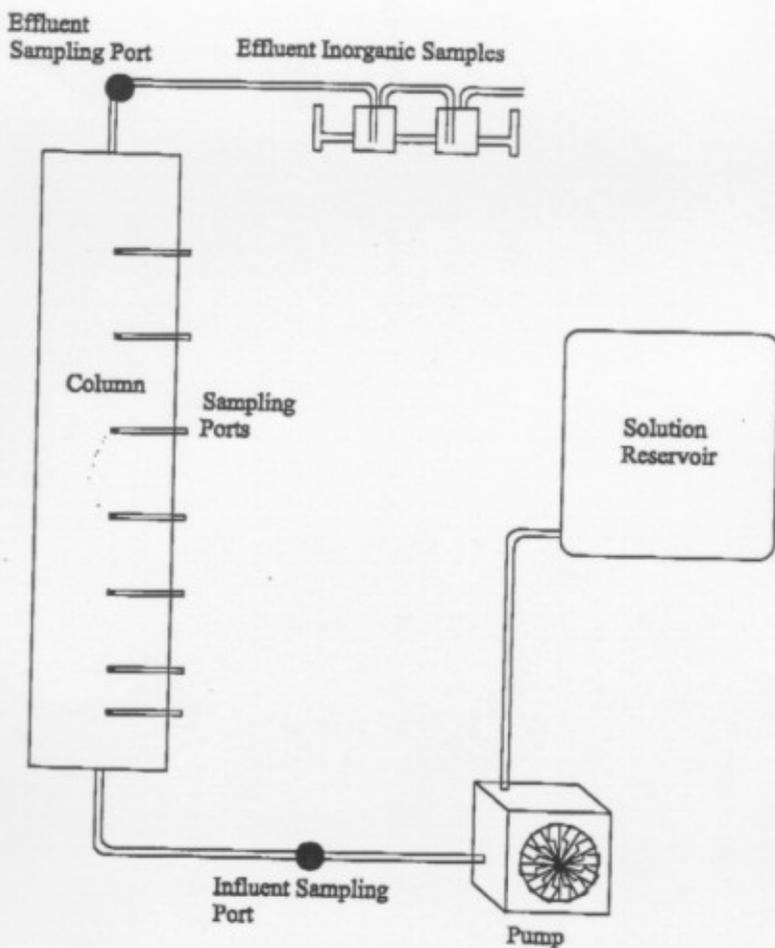
**Table 1: An Updated Preliminary Cost Estimate for Implementation of the Iron Wall Technology at Site D-4, Kelly AFB, San Antonio, TX**

Phase	Estimated Cost (US\$)	
I Data review Site Visit and Meeting <sup>a</sup>	\$1,000	
	\$3,000	
II Bench-Scale Testing <sup>b</sup>	\$25,000	
III Assistance with Field Design and Implementation	\$10,000 - \$20,000	
IV Installation	• Reactive Material	\$578,000 - \$1,898,000
	• Construction <sup>c</sup>	<u>\$500,000 - \$1,290,000</u>
	Subtotal	\$1,078,000 - \$3,188,000
	• Site License Fee (13%)	<u>\$140,000 - \$414,000</u>
	• <b>TOTAL</b>	<b>\$1,218,000 - \$3,602,000</b>
V Performance Monitoring	Variable	

<sup>a</sup> Includes travel

<sup>b</sup> Costs of sample collection and shipment are not included

<sup>c</sup> Based on cost data from other sites. Would need to be refined based on a more complete review of site data and quotation from construction contractors. Does not include costs for activities such as site preparation, permitting, soil disposal, site construction management, etc.



Schematic of the Apparatus Used in the Bench Scale Test

**APPENDIX B**

**REMEDIAL ALTERNATIVES COST TABLES AND PERMEABLE  
REACTIVE BARRIER INFORMATION**

**TABLE C.1  
COST ESTIMATE FOR  
ALTERNATIVE 1: GROUNDWATER COLLECTION TRENCH**

Assembly <sup>a/</sup>	Line Item	Qty.	Unit	Safety Level <sup>d/</sup>	Unit Price			Total Costs			Item Total	Frequency (year)	NPV <sup>b/</sup> and subtotals
					Labor	Equipment	Materials	Labor	Equipment	Materials			
<b>CONSTRUCTION</b>													
<i>Pre-Construction</i>													
	Pump test/pre-design modeling	250	HR	E	75	0	5	18,750	0	1,250	20,000		20,000
	Design system	500	HR	E	75	0	0	37,500	0	0	37,500		37,500
	Procurement	80	HR	E	75	0	0	6,000	0	0	6,000		6,000
												63,500	
<i>Well construction (4 performance monitoring wells)</i>													
33 23 1180	Mobilization/demobilization, drill equipment, crew	1	EA	D	367	735	217	448	735	217	1,400		1,400
33 23 2502	Drill and install 2" wells (20 feet deep each)	80	LF	D	0	0	26	0	0	2,080	2,080		2,080
												3,480	
<i>Installation of Collection System and Barrier Wall</i>													
	Mobilization/demobilization	1	EA	D	0	0	50,000	0	0	50,000	50,000		50,000
17 03 0103	Site grading (900' by 100')	10,000	SY	D	0.28	0.69	0	3,416	6,900	0	10,316		10,316
	80 mil HDPE vertical barrier (450' by 20' deep)	9,000	SF	D	0	0	8	0	0	72,000	72,000		72,000
	Trenching and backfilling (continuous trenching)	800	LF	D	0	0	250	0	0	200,000	200,000		200,000
19 02 0125	4-inch collection pipe in trench	800	LF	D	3	1	1	3,133	1,168	744	5,045		5,045
33 23 0603	Sump pumps (2)	2	EA	D	340	0	2,125	830	0	4,250	5,080		5,080
17 03 0255	Discharge pipe trenching (600 LF, 2' wide, 4' deep)	178	CY	D	3	1	0	690	206	0	896		896
19 01 0204	Connect to existing piping	600	LF	D	3	0	0	2,181	222	228	2,631		2,631
	Electrical	1	LS	D	0	0	12,000	0	0	12,000	12,000		12,000
	Construction management	160	HR	D	80	0	0	15,616	0	0	15,616		15,616
	Construction management travel	1	EA	E	0	0	1,000	0	0	1,000	1,000		1,000
												374,584	
<b>O &amp; M (30 years)</b>													
<i>Site Support</i>													
	Maintain groundwater extraction system (8 hours/mo.) <sup>c/</sup>	96	HR	D	75	0	0	8,784	0	0	8,784	1	109,001
33 23 0603	Replace pumps (every five years)	2	EA	D	340	0	2,125	830	0	4,250	5,080	5	10,962
	Cleanout drain line with sewer jets (every 3 years)	1	EA	E	0	0	2,000	0	0	2,000	2,000	3	7,720
	Electricity (\$150/month)	1	YR	E	0	0	1,800	0	0	1,800	1,800	1	22,336
												150,019	
<i>Monitoring</i>													
	Conduct semiannual groundwater sampling	4	EA	D	300	0	50	1,464	0	200	1,664	0.5	41,297
33 02 0509	Analytical	4	EA	E	0	0	1,276	0	0	5,104	5,104	0.5	126,671
	Project management and reporting	40	HR	E	85	0	0	3,400	0	0	3,400	1	42,191
												210,160	

<sup>a/</sup> Assembly references are from R.S. Means (1999). Line items not referenced are based on vendor quotes and/or Parsons ES experience.

<sup>b/</sup> NPV - Net-present-value calculations employ an adjustment rate of 7 percent.

<sup>c/</sup> O&M costs include weekly system checks, monthly sampling and reporting, and maintenance.

<sup>d/</sup> Safety Level D line items have labor productivity of 82% of Level E (normal conditions). (RS Means, 1999).

	Construction	O&M	Total
	441,564	360,179	801,743
Plus contingency (15% construction, 15% O&M):	507,799	414,205	922,004
Localized for Kelly AFB (R.S. Means, 1999):	426,551	347,933	<b>774,484</b>

**TABLE C.3  
COST ESTIMATE FOR  
ALTERNATIVE 3: AIR SPARGING TRENCH**

Assembly <sup>a/</sup>	Line Item	Qty.	Unit	Safety Level <sup>d/</sup>	Unit Price			Total Costs			Item Total	Frequency (year)	NPV <sup>b/</sup> and subtotals
					Labor	Equipment	Materials	Labor	Equipment	Materials			
<b>CONSTRUCTION</b>													
<i>Pre-Construction</i>													
	Pump test/pre-design modeling	250	HR	E	75	0	5	18,750	0	1,250	20,000		20,000
	Design system	650	HR	E	75	0	0	48,750	0	0	48,750		48,750
	Procurement	80	HR	E	75	0	0	6,000	0	0	6,000		6,000
												74,750	
<i>Well construction (8 performance monitoring wells)</i>													
33 23 1180	Mobilization/demobilization, drill equipment, crew	1	EA	D	367	735	217	448	735	217	1,400		1,400
33 23 2502	Drill and install 2" wells (20 feet deep each)	160	LF	D	0	0	26	0	0	4,160	4,160		4,160
												5,560	
<i>Installation of Collection System and Barrier Wall</i>													
	Mobilization/demobilization	1	EA	D	0	0	50,000	0	0	50,000	50,000		50,000
17 03 0103	Site grading (900' by 100')	10,000	SY	D	0.28	0.69	0	3,416	6,900	0	10,316		10,316
	80 mil HDPE vertical barrier (450' by 20')	9,000	SF	D	0	0	8	0	0	72,000	72,000		72,000
	Trenching and backfilling (continuous trenching)	800	LF	D	0	0	250	0	0	200,000	200,000		200,000
33 23 2502	Sparge well installation (23 wells)	460	LF	D	0	0	26	0	0	11,960	11,960		11,960
33 13 9002	10 hp blower (sparge wells and SVE system)	2	EA	D	921	0	3,405	2,248	0	6,810	9,058		9,058
17 03 0255	Pipe trenching (800 LF, 2' wide, 4' deep)	237	CY	D	3.18	1.16	0.00	920	275	0	1,195		1,195
19 01 0204	SVE and sparge well lateral piping (2 runs @ 800 LF)	1,600	LF	D	2.98	0.37	0.38	5,817	592	608	7,017		7,017
33 13 1903	Carbon adsorption unit for SVE	2	EA	D	76.77	0.00	544.00	187	0	1,088	1,275		1,275
	Electrical	1	LS	D	0	0	12,000	0	0	12,000	12,000		12,000
	Construction management	200	HR	D	80	0	0	19,520	0	0	19,520		19,520
	Construction management travel	1	EA	E	0	0	1,500	0	0	1,500	1,500		1,500
												395,841	
<b>O &amp; M (30 years)</b>													
<i>Site Support</i>													
	Maintain air sparging/SVE system (24 hours/month) <sup>c/</sup>	288	HR	D	75	0	0	26,352	0	0	26,352	1	327,003
33 13 9002	Replace blowers (every 10 years)	2	EA	D	921	0	3,405	2,248	0	6,810	9,058	10	8,135
33 13 1903	Replace SVE carbon units (every 3 months)	2	EA	D	76.77	0.00	544.00	187	0	1,088	1,275	0.25	63,302
	Electricity (\$300/month)	1	YR	E	0	0	3,600	0	0	3,600	3,600	1	44,673
												443,113	
<i>Monitoring</i>													
	Conduct semiannual groundwater sampling	8	EA	D	300	0	50	2,928	0	400	3,328	0.5	82,595
33 02 0509	Analytical	8	EA	E	0	0	1,276	0	0	10,208	10,208	0.5	253,343
	Project management and reporting	60	HR	E	85	0	0	5,100	0	0	5,100	1	63,286
												399,224	

<sup>a/</sup> Assembly references are from R.S. Means (1999). Line items not referenced are based on vendor quotes and/or Parsons ES experience.

<sup>b/</sup> NPV - Net-present-value calculations employ an adjustment rate of 7 percent.

<sup>c/</sup> O&M costs include weekly system checks, monthly sampling and reporting, and maintenance.

<sup>d/</sup> Safety Level D line items have labor productivity of 82% of Level E (normal conditions). (RS Means, 1999).

	Construction	O&M	Total
	476,150	842,336	1,318,487
Plus contingency (15% construction, 15% O&M):	547,573	968,687	1,516,260
Localized for Kelly AFB (R.S. Means, 1999):	459,961	813,697	<b>1,273,658</b>

**TABLE C.2  
COST ESTIMATE FOR  
ALTERNATIVE 2: PERMEABLE REACTION WALL**

Assembly <sup>a/</sup>	Line Item	Qty.	Unit	Safety Level <sup>d/</sup>	Unit Price			Total Costs			Item Total	Frequency (year)	NPV <sup>b/</sup> and subtotals
					Labor	Equipment	Materials	Labor	Equipment	Materials			
<b>CONSTRUCTION</b>													
<i>Pre-Construction</i>													
	Pump test/pre-design modeling	250	HR	E	75	0	5	18,750	0	1,250	20,000		20,000
	Design system	700	HR	E	75	0	0	52,500	0	0	52,500		52,500
	Procurement	80	HR	E	75	0	0	6,000	0	0	6,000		6,000
												78,500	
<i>Well construction (8 performance monitoring wells)</i>													
33 23 1180	Mobilization/demobilization, drill equipment, crew	1	EA	D	367	735	217	448	735	217	1,400		1,400
33 23 2502	Drill and install 2" wells (20 feet deep each)	160	LF	D	0	0	26	0	0	4,160	4,160		4,160
												5,560	
<i>Installation of Collection System and Barrier Wall</i>													
	Mobilization/demobilization	1	EA	D	0	0	50,000	0	0	50,000	50,000		50,000
17 03 0103	Site grading (900' by 100')	10,000	SY	D	0.28	0.69	0	3,416	6,900	0	10,316		10,316
	80 mil HDPE vertical barrier (450' by 20')	9,000	SF	D	0	0	8	0	0	72,000	72,000		72,000
	Trenching and backfilling (continuous trenching) (assumes multiple passes to achieve req'd trench width)	1,500	LF	D	0	0	250	0	0	375,000	375,000		375,000
Vendor quote	Iron filings	4,608	TON	D	0	0	400	0	0	1,843,200	1,843,200		1,843,200
Vendor quote	Proprietary license fee	1	LS	D	0	0	414,000	0	0	414,000	414,000		414,000
	Compost trench excavation (continuous trenching)	800	LF	D	0	0	250	0	0	200,000	200,000		200,000
Vendor quote	Compost	1,000	CY	D	0	0	50	0	0	50,000	50,000		50,000
	Construction management	160	HR	D	80	0	0	15,616	0	0	15,616		15,616
	Construction management travel	1	EA	E	0	0	1,000	0	0	1,000	1,000		1,000
												3,031,132	
<b>O &amp; M (30 years)</b>													
<i>Site Support</i>													
	Maintain system (4 hours/month) <sup>c/</sup>	48	HR	D	75	0	0	4,392	0	0	4,392	1	54,501
33 23 1101	Auger drilling along every 5' of face of wall (every 10 years)	3,200	LF	D	5	11	0	20,925	34,400	0	55,325	10	49,690
												104,190	
<i>Monitoring</i>													
	Conduct semiannual groundwater sampling	8	EA	D	300	0	50	2,928	0	400	3,328	0.5	82,595
33 02 0509	Analytical	8	EA	E	0	0	1,276	0	0	10,208	10,208	0.5	253,343
	Project management and reporting	60	HR	E	85	0	0	5,100	0	0	5,100	1	63,286
												399,224	

<sup>a/</sup> Assembly references are from R.S. Means (1999). Line items not referenced are based on vendor quotes and/or Parsons ES experience.

<sup>b/</sup> NPV - Net-present-value calculations employ an adjustment rate of 7 percent.

<sup>c/</sup> O&M costs include weekly system checks, monthly sampling and reporting, and maintenance.

<sup>d/</sup> Safety Level D line items have labor productivity of 82% of Level E (normal conditions). (RS Means, 1999).

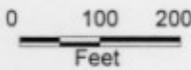
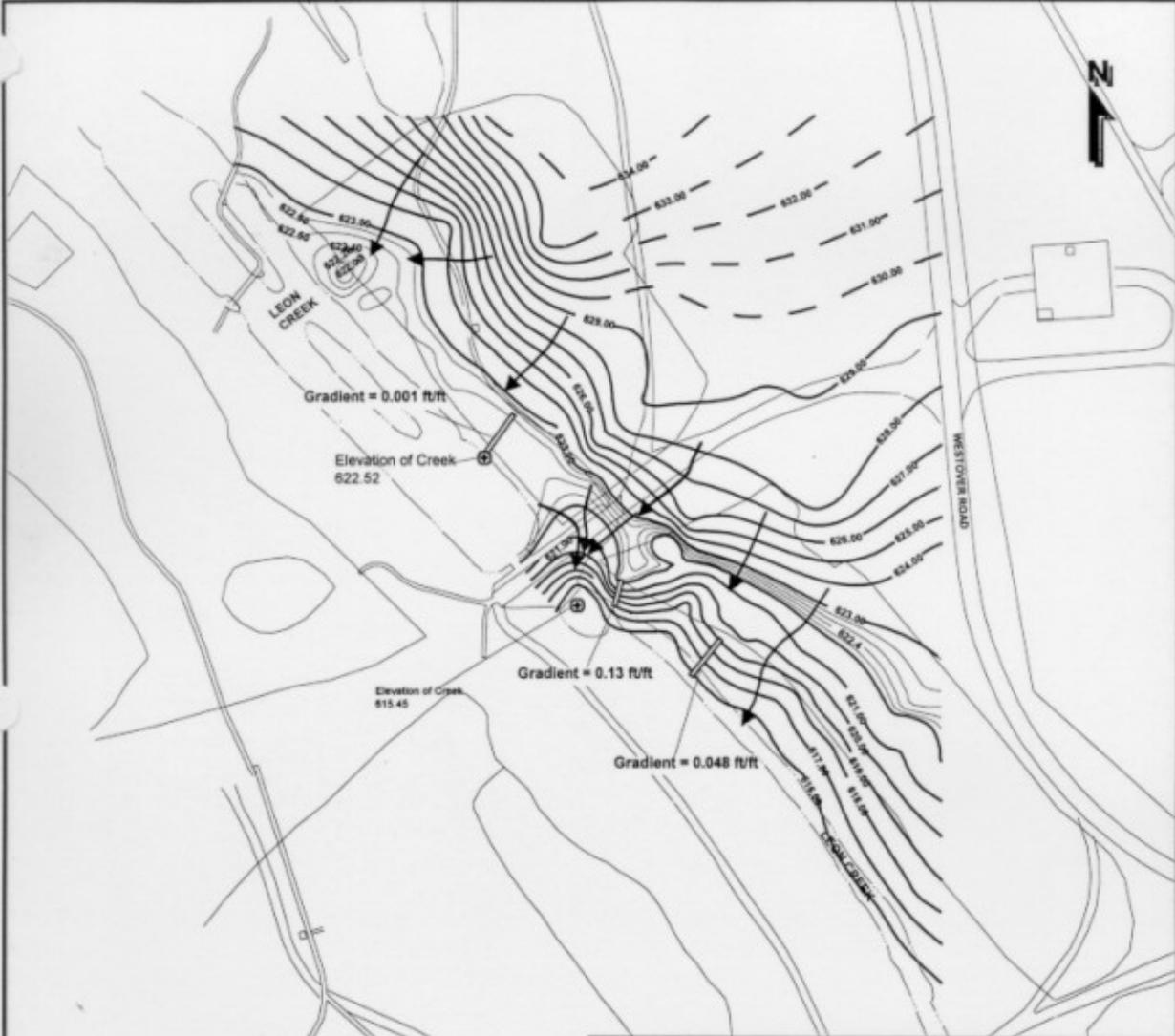
	Construction	O&M	Total
	3,115,192	503,414	3,618,606
Plus contingency (25% construction, 15% O&M):	3,893,990	578,926	4,472,916
Localized for Kelly AFB (R.S. Means, 1999):	3,270,951	486,298	<b>3,757,249</b>

**APPENDIX C**

**GROUNDWATER-TO-SURFACE-WATER DISCHARGE  
CALCULATIONS**



FILE: S:\ES\REM\FD\RPO\KELLY\MAP\INFO\WORK\SPACES\GRADIENTS.WOP '07/00 TIME: 1:00



**LEGEND**

- Location of Measured Hydraulic Gradient
- ⊕ Elevation of Leon Creek
- ← Inferred Direction of Groundwater Flow
- Leon Creek
- Potentiometric Surface Contour Line (Dashed where Inferred)

**LOCATION AND VALUES OF  
HYDRAULIC GRADIENTS  
OF SURFICIAL AQUIFER  
JANUARY 2000**

Site D4 Contaminant Plume  
Remedial Process Optimization  
Kelly AFB, Texas

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**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

Denver, Colorado

**CALCULATED FLOW TO LEON CREEK FROM SURFICIAL AQUIFER**  
**SITE D-4 CONTAMINANT PLUME**  
**REMEDIAL PROCESS OPTIMIZATION**  
**KELLY AFB, TEXAS**

	Length (ft)	Height (ft)	Area (ft <sup>2</sup> )	Gradient (ft/ft)	Hydraulic Conductivity (ft/day)	Flow (ft <sup>3</sup> /day)
Area 1	215	12.1	2601.5	0.001	24	62.436
Area 2	230	10.4	2392	0.001	24	57.408
Area 3	200	10.4	2080	0.13	24	6489.6
Area 4	215	6	1290	0.048	24	1486.08
<b>Total Flow =</b>						<b>8,096 ft<sup>3</sup>/day</b>
<b>Total Flow =</b>						<b>0.094 cfs</b>

**APPENDIX D**  
**DILUTION MODELING RESULTS**

ANALYSES OF LIMITS FOR TOXIC MATERIALS IN WASTEWATER DISCHARGES  
'TEXTOX' 2.3

TEXAS NATURAL RESOURCE  
CONSERVATION COMMISSION

WATERSHED MANAGEMENT DIVISION  
PERMITTING SECTION  
03-27-00

CONDITIONS/ASSUMPTIONS

TSS : 6.00  
HARDNESS : 223.00  
pH : 7.30  
CHLORIDE : 58.00

PERMITTEE : KELLY  
PERMIT # : 03955

PREPARED BY: RMP

SEGMENT NUMBER : 1906  
SEGMENT NAME :

THESE ANALYSES ARE  
BASED ON

AQUATIC LIFE  
HUMAN HEALTH

CRITERIA

PERCENTAGE OF EFFLUENT FOR HUMAN HEALTH : 3.26%  
PERCENTAGE OF EFFLUENT AT EDGE OF ZID : 39.96%  
PERCENTAGE OF EFFLUENT AT EDGE OF MIXING ZONE : 14.26%  
WASTEWATER FLOW TO CALCULATE AQUATIC LIFE : 0.10 MGD  
WASTEWATER FLOW TO CALCULATE HUMAN HEALTH : 0.10 MGD  
7 DAY, 2 YEAR LOW FLOW : 0.93 CFS  
HARMONIC MEAN FLOW : 4.59 CFS

THE RECEIVING WATER IS PERENNIAL STREAM OR RIVER  
DRINKING WATER AND FRESHWATER FISH TISSUE STANDARDS APPLY

TDS	ANN AVG:	DLY AVG:	DLY MAX:	mg/l
-----	----------	----------	----------	------

COMMENTS: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

POLLUTANT	DAILY AVERAGE $\mu\text{g/l}$	DAILY MAXIMUM $\mu\text{g/l}$	MAL $\mu\text{g/l}$
ALDRIN	6.3241	13.3796	0.05
ALUMINUM	2089.0647	4419.7217	30.00
ARSENIC	1348.1187	2852.1421	10.00
CADMIUM	70.1816	148.4795	1.00
CARBARYL	4.2161	8.9197	5.00
CHLORDANE	0.0341	0.0722	0.15
CHLORPYRIFOS	0.1750	0.3702	0.05
CHROME (TRI)	15059.4063	31860.3770	10.00
CHROME (HEX)	33.7286	71.3578	10.00
COPPER	229.8670	486.3173	10.00
CYANIDE	84.8300	179.4704	20.00
4-4-DDT	0.0079	0.0168	0.10
DEMETON	0.7935	1.6789	0.20
DICOFOL	125.0066	264.4697	20.00
DIELDRIN	0.0151	0.0319	0.10
DIURON	442.6878	936.5708	0.00
ENDOSULFAN I (alpha)	0.4444	0.9402	0.10
ENDOSULFAN II (beta)	0.4444	0.9402	0.10
ENDOSULFAN SULFATE	0.4444	0.9402	0.10
ENDRIN	0.0183	0.0386	0.10
GUTHION	0.0794	0.1679	0.10
HEPTACHLOR	0.0302	0.0638	0.05
HEXACHLOROCYCLOHEXANE	0.6348	1.3431	0.05
LEAD	352.7256	746.2426	5.00
MALATHION	0.0794	0.1679	0.10
MERCURY	5.0593	10.7037	0.20
METHOXYCHLOR	0.2381	0.5037	2.00
MIREX	0.0079	0.0168	0.20
NICKEL	5075.5205	10738.0059	10.00
PCB (TOTAL)	0.1111	0.2350	1.00
PARATHION	0.1032	0.2183	0.10
PHENANTHRENE	63.2411	133.7958	10.00
PENTACHLOROPHENOL	25.8486	54.6865	50.00
SELENIUM	39.6773	83.9431	10.00
SILVER (TOTAL EQUIVALENT)	31.7044	67.0752	2.00

POLLUTANT	DAILY AVERAGE µg/l	DAILY MAXIMUM µg/l	MAL µg/l
TOXAPHENE	0.0016	0.0034	5.00
TRIBUTYL TIN	0.1905	0.4029	0.01
2-4-5-TRICHLOROPHENOL	286.6931	606.5411	50.00
ZINC	1535.5430	3248.6658	5.00

WAPMIL FINE NOMPHILA

## AQUATIC LIFE WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	ACUTE CRIT CHRON CRIT	WLAA WLAC	LTAA LTAC	DLY AVG DLY MAX
ALDRIN	100.00	3.0000 0.0000	7.508 0.000	4.302 0.000	6.3241 13.3796
ALUMINUM	100.00	991.0000 0.0000	2480.161 0.000	1421.132 0.000	2089.0647 4419.7217
ARSENIC	56.29	360.0000 190.0000	1600.502 2366.273	917.088 1822.031	1348.1187 2852.1421
CADMIUM	24.07	83.2535 2.1291	865.483 62.003	495.922 47.743	70.1816 148.4795
CARBARYL	100.00	2.0000 0.0000	5.005 0.000	2.868 0.000	4.2161 8.9197
CHLORDANE	100.00	2.4000 0.0043	6.006 0.030	3.442 0.023	0.0341 0.0722
CHLORPYRIFOS	100.00	0.0830 0.0410	0.208 0.287	0.119 0.221	0.1750 0.3702
CHROME (TRI)	21.04	3349.1897 399.2044	39846.160 13304.538	22831.850 10244.494	15059.4063 31860.3770
CHROME (HEX)	100.00	16.0000 11.0000	40.043 77.118	22.945 59.381	33.7286 71.3578
COPPER	37.47	40.8635 25.3919	272.901 475.030	156.372 365.773	229.8670 486.3173
CYANIDE	100.00	45.7800 10.6900	114.573 74.945	65.650 57.708	84.8300 179.4704
4-4-DDT	100.00	1.1000 0.0010	2.753 0.007	1.577 0.005	0.0079 0.0168

## AQUATIC LIFE WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	ACUTE CRIT CHRON CRIT	WLAA WLAC	LTAA LTAC	DLY AVG DLY MAX
DEMETON	100.00	0.0000 0.1000	0.000 0.701	0.000 0.540	0.7935 1.6789
DICOFOL	100.00	59.3000 19.8000	148.409 138.813	85.038 106.886	125.0066 264.4697
DIELDRIN	100.00	2.5000 0.0019	6.257 0.013	3.585 0.010	0.0151 0.0319
DIURON	100.00	210.0000 70.0000	525.564 490.752	301.148 377.879	442.6878 936.5708
ENDOSULFAN I(alpha)	100.00	0.2200 0.0560	0.551 0.393	0.315 0.302	0.4444 0.9402
ENDOSULFAN II(beta)	100.00	0.2200 0.0560	0.551 0.393	0.315 0.302	0.4444 0.9402
ENDOSULFAN SULFATE	100.00	0.2200 0.0560	0.551 0.393	0.315 0.302	0.4444 0.9402
ENDRIN	100.00	0.1800 0.0023	0.450 0.016	0.258 0.012	0.0183 0.0386
GUTHION	100.00	0.0000 0.0100	0.000 0.070	0.000 0.054	0.0794 0.1679
HEPTACHLOR	100.00	0.5200 0.0038	1.301 0.027	0.746 0.021	0.0302 0.0638
HEXACHLOROCYCLOHEXANE	100.00	2.0000 0.0800	5.005 0.561	2.868 0.432	0.6348 1.3431
LEAD	19.87	226.6325 8.8315	2854.676 311.623	1635.729 239.949	352.7256 746.2426

## AQUATIC LIFE WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	ACUTE CRIT CHRON CRIT	WLAA WLAC	LTAA LTAC	DLY AVG DLY MAX
MALATHION	100.00	0.0000 0.0100	0.000 0.070	0.000 0.054	0.0794 0.1679
MERCURY	100.00	2.4000 1.3000	6.006 9.114	3.442 7.018	5.0593 10.7037
METHOXYCHLOR	100.00	0.0000 0.0300	0.000 0.210	0.000 0.162	0.2381 0.5037
MIREX	100.00	0.0000 0.0010	0.000 0.007	0.000 0.005	0.0079 0.0168
NICKEL	48.58	2795.2234 310.7433	14398.908 4484.072	8250.574 3452.735	5075.5205 10738.0059
PCB (TOTAL)	100.00	2.0000 0.0140	5.005 0.098	2.868 0.076	0.1111 0.2350
PARATHION	100.00	0.0650 0.0130	0.163 0.091	0.093 0.070	0.1032 0.2183
PHENANTHRENE	100.00	30.0000 30.0000	75.081 210.322	43.021 161.948	63.2411 133.7958
PENTACHLOROPHENOL	100.00	12.2619 7.7408	30.688 54.268	17.584 41.787	25.8486 54.6865
SELENIUM	100.00	20.0000 5.0000	50.054 35.054	28.681 26.991	39.6773 83.9431
SILVER (TOTAL EQUIVALENT)	6.12	0.9200 0.0000	37.640 0.000	21.568 0.000	31.7044 67.0752
TOXAPHENE	100.00	0.7800 0.0002	1.952 0.001	1.119 0.001	0.0016 0.0034

## AQUATIC LIFE WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	ACUTE CRIT CHRON CRIT	WLAA WLAC	LTAA LTAC	DLY AVG DLY MAX
TRIBUTYL TIN	100.00	0.1300 0.0240	0.325 0.168	0.186 0.130	0.1905 0.4029
2-4-5-TRICHLOROPHENOL	100.00	136.0000 64.0000	340.365 448.687	195.029 345.489	286.6931 606.5411
ZINC	31.70	230.8797 209.1176	1823.014 4625.434	1044.587 3561.584	1535.5430 3248.6658

POLLUTANT	DLY AVG µg/l	70% DLY AVG µg/l	85% DLY AVG µg/l
ALDRIN	6.3241	4.4269	5.3755
ALUMINUM	2089.0647	1462.3453	1775.7050
ARSENIC	1348.1187	943.6831	1145.9009
CADMIUM	70.1816	49.1271	59.6544
CARBARYL	4.2161	2.9513	3.5837
CHLORDANE	0.0341	0.0239	0.0290
CHLORPYRIFOS	0.1750	0.1225	0.1487
CHROME (TRI)	15059.4063	10541.5844	12800.4953
CHROME (HEX)	33.7286	23.6100	28.6693
COPPER	229.8670	160.9069	195.3870
CYANIDE	84.8300	59.3810	72.1055
4-4-DDT	0.0079	0.0056	0.0067
DEMETON	0.7935	0.5555	0.6745
DICOFOL	125.0066	87.5046	106.2556
DIELDRIN	0.0151	0.0106	0.0128
DIURON	442.6878	309.8815	376.2846
ENDOSULFAN I(alpha)	0.4444	0.3111	0.3777
ENDOSULFAN II(beta)	0.4444	0.3111	0.3777
ENDOSULFAN SULFATE	0.4444	0.3111	0.3777
ENDRIN	0.0183	0.0128	0.0155
GUTHION	0.0794	0.0555	0.0675
HEPTACHLOR	0.0302	0.0211	0.0256
HEXACHLOROCYCLOHEXANE	0.6348	0.4444	0.5396
LEAD	352.7256	246.9079	299.8167
MALATHION	0.0794	0.0555	0.0675
MERCURY	5.0593	3.5415	4.3004
METHOXYCHLOR	0.2381	0.1666	0.2024
MIREX	0.0079	0.0056	0.0067
NICKEL	5075.5205	3552.8644	4314.1924
PCB (TOTAL)	0.1111	0.0778	0.0944
PARATHION	0.1032	0.0722	0.0877
PHENANTHRENE	63.2411	44.2688	53.7549
PENTACHLOROPHENOL	25.8486	18.0940	21.9713
SELENIUM	39.6773	27.7741	33.7257
SILVER (TOTAL EQUIVALENT)	31.7044	22.1931	26.9487

POLLUTANT	DLY AVG μg/l	70% DLY AVG μg/l	85% DLY AVG μg/l
TOXAPHENE	0.0016	0.0011	0.0013
TRIBUTYLTIN	0.1905	0.1333	0.1619
2-4-5-TRICHLOROPHENOL	286.6931	200.6851	243.6891
ZINC	1535.5430	1074.8801	1305.2115

\* POLLUTANT LIMITS EXPRESSED AS ANNUAL AVERAGE AND DAILY MAX  
 ALL DAILY LIMITS ARE LISTED IN MICROGRAMS/LITER

POLLUTANT	DAILY AVERAGE μg/l	DAILY MAXIMUM μg/l	MAL μg/l
ALDRIN	1.3080	2.7673	0.05
ALPHA-HEXACHLOROCYCLOHEXANE	27.0406	57.2083	0.05
ARSENIC	3723.6909	7878.0127	10.00
BARIUM	83846.7578	177390.0781	10.00
BENZENE	209.6169	443.4752	10.00
BENZIDINE	0.0461	0.0976	50.00
BENZO (a) ANTHRACENE	1.0942	2.3149	10.00
BENZO (a) PYRENE	1.0942	2.3149	10.00
BETA-HEXACHLOROCYCLOHEXANE	94.7468	200.4508	0.05
BIS (CHLOROMETHYL) ETHER	0.8678	1.8360	0.00
CADMIUM	870.7159	1842.1268	1.00
CARBON TETRACHLORIDE	209.6169	443.4752	10.00
CHLORDANE	0.8804	1.8626	0.15
CHLOROBENZENE	54710.0078	115747.0234	10.00
CHLOROFORM	N/A	N/A	10.00
CHROMIUM	19929.5156	42163.8047	10.00
CRYSENE	1.0942	2.3149	10.00
CRESOLS	169747.7500	359126.2188	10.00
CYANIDE (free)	8384.6758	17739.0078	20.00
4-4-DDD	12.4512	26.3424	0.10
4-4-DDE	2.2806	4.8250	0.10
4-4-DDT	2.2094	4.6742	0.10
2-4-D	2934.6365	6208.6528	10.00
DANITOL	29.7237	62.8848	0.00
DIBROMOCHLOROMETHANE	4192.3379	8869.5039	10.00
1-2-DIBROMOETHANE	2.1716	4.5944	2.00
DIELDRIN	0.0503	0.1064	0.10
P-DICHLOROENZENE	3144.2532	6652.1274	10.00
1-2-DICHLOROETHANE	209.6169	443.4752	10.00
1-1-DICHLOROETHYLENE	293.4636	620.8652	10.00
DICOFOL	9.0135	19.0694	20.00
DIOXINS-FURANS*	30.6659	88.6950	10.00

\* DIOXINS-FURANS LIMITS EXPRESSED AS ANNUAL AVERAGE AND DAILY MAX  
ALL DIOXIN-FURANS VALUES ARE LISTED IN PICOGRAMS/LITER

POLLUTANT	DAILY AVERAGE $\mu\text{g}/\text{l}$	DAILY MAXIMUM $\mu\text{g}/\text{l}$	MAL $\mu\text{g}/\text{l}$
ENDRIN	83.8468	177.3901	0.10
FLUORIDE	167693.5156	354780.1563	500.00
GAMMA HEXACHLOROCYCLOHEXANE	8.3847	17.7390	0.05
HEPTACHLOR	0.7420	1.5699	0.05
HEPTACHLOR EPOXIDE	8.3847	17.7390	1.00
HEXACHLOROBENZENE	0.5408	1.1442	10.00
HEXACHLOROBUTADIENE	391.5643	828.4116	10.00
HEXACHLOROETHANE	3538.3330	7485.8613	20.00
HEXACHLOROPHENE	2.2261	4.7097	10.00
LEAD	1055.0054	2232.0181	5.00
MERCURY	0.5115	1.0821	0.20
METHOXYCHLOR	1676.9349	3547.8013	2.00
METHYL ETHYL KETONE	184924.0000	391233.7813	50.00
MIREX	0.7169	1.5167	0.20
NITRATE-N	419233.7500	886950.3125	1000.00
NITROBENZENE	1752.3970	3707.4521	10.00
N-NITROSODIETHYLAMINE	1.6015	3.3882	20.00
N-NITROSO-DI-N-BUTYLAMINE	77.1390	163.1989	20.00
PCB	0.0545	0.1153	1.00
PENTACHLOROBENZENE	45.6965	96.6776	20.00
PENTACHLOROPHENOL	5408.1157	11441.6592	50.00
PYRIDINE	3693.4497	7814.0327	20.00
SELENIUM	2096.1689	4434.7520	10.00
1-2-4-5-TETRACHLOROBENZENE	59.9504	126.8339	20.00
TETRACHLOROETHYLENE	209.6169	443.4752	10.00
TOXAPHENE	1.8446	3.9026	5.00
SILVEX	2096.1689	4434.7520	2.00
2-4-5-TRICHLOROPHENOL	116001.9844	245419.1563	50.00
TRICHLOROETHYLENE	209.6169	443.4752	10.00
1-1-1-TRICHLOROETHANE	8384.6758	17739.0078	10.00
TOTAL TRIHALOMETHANES	4192.3379	8869.5039	10.00
VINYL CHLORIDE	83.8468	177.3901	10.00

POLLUTANT	DLY AVG μg/l	70% DLY AVG μg/l	85% DLY AVG μg/l
ALDRIN	1.3080	0.9156	1.1118
ALPHA-HEXACHLOROCYCLOHEXANE	27.0406	18.9284	22.9845
ARSENIC	3723.6909	2606.5836	3165.1373
BARIUM	83846.7578	58692.7305	71269.7441
BENZENE	209.6169	146.7318	178.1743
BENZIDINE	0.0461	0.0323	0.0392
BENZO (a) ANTHRACENE	1.0942	0.7659	0.9301
BENZO (a) PYRENE	1.0942	0.7659	0.9301
BETA-HEXACHLOROCYCLOHEXANE	94.7468	66.3228	80.5348
BIS (CHLOROMETHYL) ETHER	0.8678	0.6075	0.7376
CADMIUM	870.7159	609.5011	740.1085
CARBON TETRACHLORIDE	209.6169	146.7318	178.1743
CHLORDANE	0.8804	0.6163	0.7483
CHLOROBENZENE	54710.0078	38297.0055	46503.5066
CHLOROFORM	N/A	N/A	N/A
CHROMIUM	19929.5156	13950.6609	16940.0883
CRYSENE	1.0942	0.7659	0.9301
CRESOLS	169747.7500	118823.4250	144285.5875
CYANIDE (free)	8384.6758	5869.2730	7126.9744
4-4-DDD	12.4512	8.7159	10.5836
4-4-DDE	2.2806	1.5964	1.9385
4-4-DDT	2.2094	1.5466	1.8780
2-4-D	2934.6365	2054.2455	2494.4410
DANITOL	29.7237	20.8066	25.2651
DIBROMOCHLOROMETHANE	4192.3379	2934.6365	3563.4872
1-2-DIBROMOETHANE	2.1716	1.5201	1.8459
DIELDRIN	0.0503	0.0352	0.0428
P-DICHLOROBENZENE	3144.2532	2200.9772	2672.6152
1-2-DICHLOROETHANE	209.6169	146.7318	178.1743
1-1-DICHLOROETHYLENE	293.4636	205.4245	249.4441
DICOFOL	9.0135	6.3095	7.6615
DIOXINS-FURANS*	30.6659	21.4661	26.0660
ENDRIN	83.8468	58.6927	71.2697
FLUORIDE	167693.5156	117385.4609	142539.4883
GAMMA HEXACHLOROCYCLOHEXANE	8.3847	5.8693	7.1270

POLLUTANT	DLY AVG µg/l	70% DLY AVG µg/l	85% DLY AVG µg/l
HEPTACHLOR	0.7420	0.5194	0.6307
HEPTACHLOR EPOXIDE	8.3847	5.8693	7.1270
HEXACHLOROBENZENE	0.5408	0.3786	0.4597
HEXACHLOROBUTADIENE	391.5643	274.0950	332.8297
HEXACHLOROETHANE	3538.3330	2476.8331	3007.5831
HEXACHLOROPHENE	2.2261	1.5583	1.8922
LEAD	1055.0054	738.5038	896.7546
MERCURY	0.5115	0.3580	0.4347
METHOXYCHLOR	1676.9349	1173.8545	1425.3947
METHYL ETHYL KETONE	184924.0000	129446.8000	157185.4000
MIREX	0.7169	0.5018	0.6094
NITRATE-N	419233.7500	293463.6250	356348.6875
NITROBENZENE	1752.3970	1226.6779	1489.5374
N-NITROSODIETHYLAMINE	1.6015	1.1210	1.3613
N-NITROSO-DI-N-BUTYLAMINE	77.1390	53.9973	65.5682
PCB	0.0545	0.0382	0.0463
PENTACHLOROBENZENE	45.6965	31.9875	38.8420
PENTACHLOROPHENOL	5408.1157	3785.6810	4596.8984
PYRIDINE	3693.4497	2585.4148	3139.4323
SELENIUM	2096.1689	1467.3183	1781.7436
1-2-4-5-TETRACHLOROBENZENE	59.9504	41.9653	50.9579
TETRACHLOROETHYLENE	209.6169	146.7318	178.1743
TOXAPHENE	1.8446	1.2912	1.5679
SILVEX	2096.1689	1467.3183	1781.7436
2-4-5-TRICHLOROPHENOL	116001.9844	81201.3891	98601.6867
TRICHLOROETHYLENE	209.6169	146.7318	178.1743
1-1-1-TRICHLOROETHANE	8384.6758	5869.2730	7126.9744
TOTAL TRIHALOMETHANES	4192.3379	2934.6365	3563.4872
VINYL CHLORIDE	83.8468	58.6927	71.2697

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
ALDRIN	100.00	0.031	0.957	0.890	1.3080 2.7673
ALPHA-HEXACHLOROCYCLOHEXANE	100.00	0.645	19.780	18.395	27.0406 57.2083
ARSENIC	56.29	50.000	2723.788	2533.123	3723.6909 7878.0127
BARIUM	100.00	2000.000	61331.836	57038.609	83846.7578 177390.0781
BENZENE	100.00	5.000	153.330	142.597	209.6169 443.4752
BENZIDINE	100.00	0.001	0.034	0.031	0.0461 0.0976
BENZO (a) ANTHRACENE	100.00	0.026	0.800	0.744	1.0942 2.3149
BENZO (a) PYRENE	100.00	0.026	0.800	0.744	1.0942 2.3149
BETA-HEXACHLOROCYCLOHEXANE	100.00	2.260	69.305	64.454	94.7468 200.4508
BIS (CHLOROMETHYL) ETHER	100.00	0.021	0.635	0.590	0.8678 1.8360
CADMIUM	24.07	5.000	636.907	592.324	870.7159 1842.1268
CARBON TETRACHLORIDE	100.00	5.000	153.330	142.597	209.6169 443.4752

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
CHLORDANE	100.00	0.021	0.644	0.599	0.8804 1.8626
CHLOROBENZENE	100.00	1305.000	40019.023	37217.691	54710.0078 115747.0234
CHLOROFORM	100.00	0.000	0.000	0.000	0.0000 0.0000
CHROMIUM	21.04	100.000	14577.949	13557.493	19929.5156 42163.8047
CRYSENE	100.00	0.026	0.800	0.744	1.0942 2.3149
CRESOLS	100.00	4049.000	124166.305	115474.664	169747.7500 359126.2188
CYANIDE (free)	100.00	200.000	6133.184	5703.861	8384.6758 17739.0078
4-4-DDD	100.00	0.297	9.108	8.470	12.4512 26.3424
4-4-DDE	100.00	0.054	1.668	1.551	2.2806 4.8250
4-4-DDT	100.00	0.053	1.616	1.503	2.2094 4.6742
2-4-D	100.00	70.000	2146.614	1996.351	2934.6365 6208.6528
DANITOL	100.00	0.709	21.742	20.220	29.7237 62.8848

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
DIBROMOCHLOROMETHANE	100.00	100.000	3066.592	2851.930	4192.3379 8869.5039
1-2-DIBROMOETHANE	100.00	0.052	1.588	1.477	2.1716 4.5944
DIELDRIN	100.00	0.001	0.037	0.034	0.0503 0.1064
P-DICHLOROBENZENE	100.00	75.000	2299.944	2138.948	3144.2532 6652.1274
1-2-DICHLOROETHANE	100.00	5.000	153.330	142.597	209.6169 443.4752
1-1-DICHLOROETHYLENE	100.00	7.000	214.661	199.635	293.4636 620.8652
DICOFOL	100.00	0.215	6.593	6.132	9.0135 19.0694
DIOXINS-FURANS*	100.00	0.000	0.000	0.000	30.6659 88.6950
ENDRIN	100.00	2.000	61.332	57.039	83.8468 177.3901
FLUORIDE	100.00	4000.000	122663.672	114077.219	167693.5156 354780.1563
GAMMA HEXACHLOROCYCLOHEXANE	100.00	0.200	6.133	5.704	8.3847 17.7390
HEPTACHLOR	100.00	0.018	0.543	0.505	0.7420 1.5699

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
HEPTACHLOR EPOXIDE	100.00	0.200	6.133	5.704	8.3847 17.7390
HEXACHLOROBENZENE	100.00	0.013	0.396	0.368	0.5408 1.1442
HEXACHLOROBUTADIENE	100.00	9.340	286.420	266.370	391.5643 828.4116
HEXACHLOROETHANE	100.00	84.400	2588.204	2407.029	3538.3330 7485.8613
HEXACHLOROPHENE	100.00	0.053	1.628	1.514	2.2261 4.7097
LEAD	19.87	5.000	771.710	717.691	1055.0054 2232.0181
MERCURY	100.00	0.012	0.374	0.348	0.5115 1.0821
METHOXYCHLOR	100.00	40.000	1226.637	1140.772	1676.9349 3547.8013
METHYL ETHYL KETONE	100.00	4411.000	135267.359	125798.641	184924.0000 391233.7813
MIREX	100.00	0.017	0.524	0.488	0.7169 1.5167
NITRATE-N	100.00	10000.000	306659.188	285193.031	419233.7500 886950.3125
NITROBENZENE	100.00	41.800	1281.835	1192.107	1752.3970 3707.4521

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
N-NITROSODIETHYLAMINE	100.00	0.038	1.171	1.089	1.6015 3.3882
N-NITROSO-DI-N-BUTYLAMINE	100.00	1.840	56.425	52.476	77.1390 163.1989
PCB	100.00	0.001	0.040	0.037	0.0545 0.1153
PENTACHLOROBENZENE	100.00	1.090	33.426	31.086	45.6965 96.6776
PENTACHLOROPHENOL	100.00	129.000	3955.904	3678.990	5408.1157 11441.6592
PYRIDINE	100.00	88.100	2701.667	2512.551	3693.4497 7814.0327
SELENIUM	100.00	50.000	1533.296	1425.965	2096.1689 4434.7520
1-2-4-5-TETRACHLOROBENZENE	100.00	1.430	43.852	40.783	59.9504 126.8339
TETRACHLOROETHYLENE	100.00	5.000	153.330	142.597	209.6169 443.4752
TOXAPHENE	100.00	0.044	1.349	1.255	1.8446 3.9026
SILVEX	100.00	50.000	1533.296	1425.965	2096.1689 4434.7520
2-4-5-TRICHLOROPHENOL	100.00	2767.000	84852.594	78912.914	116001.9844 245419.1563

## HUMAN HEALTH WORKSHEET

KELLY, 03955

POLLUTANT	% DISSOLVED	CRITERIA	WLA	LTA	DLY AVG DLY MAX
TRICHLOROETHYLENE	100.00	5.000	153.330	142.597	209.6169 443.4752
1-1-1-TRICHLOROETHANE	100.00	200.000	6133.184	5703.861	8384.6758 17739.0078
TOTAL TRIHALOMETHANES	100.00	100.000	3066.592	2851.930	4192.3379 8869.5039
VINYL CHLORIDE	100.00	2.000	61.332	57.039	83.8468 177.3901

**APPENDIX E**  
**REGULATORY INFORMATION**



# TNRCC Regulatory Guidance

Remediation

RG-366/TRRP-1

February 2000

## SUBJECT: An Introduction to the Texas Risk Reduction Program

**Objectives:** This informational pamphlet introduces a new TNRCC environmental cleanup regulation and will cover the following:

- Is the TRRP rule in effect yet?
- What types of sites does it apply to?
- Why is there a new rule?
- What is regulated under TRRP?
- Is the TRRP rule different from the 1993 rule?
- If I switch to the TRRP, do I have to start over?
- If I will be using the TRRP, what should I do?
- List of planned TRRP guidance.

**Audience:** General Public, Regulated Community, and Environmental Professionals. In this document, "you" refers specifically to the person regulated by or implementing the TRRP rule.

**References:** The regulatory citation for the Texas Risk Reduction Program (TRRP) Rule is 30 TAC 350.

The TRRP Rule and Preamble are online at <http://www.tnrcc.state.tx.us/oprd/rules/indxpdf5.html>.

The TRRP Rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350 (30 TAC 350), and was published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). Download Tier 1 PCL Tables, toxicity factors, and other TRRP information at <http://www.tnrcc.state.tx.us/permitting/trrp.htm>.

**Contacts:** Technical Support Section at 512/239-0310.

Corrective Action Section at 512/239-2343. Responsible Party Remediation Section at 512/239-2200. Site Assessment & Management Section at 512/239-2509. Superfund Cleanup Section at 512/239-2425. Voluntary Cleanup Program Section at 512/239-5891.

The Texas Natural Resource Conservation Commission (TNRCC) has adopted a new rule, the Texas Risk Reduction Program (TRRP). TRRP most commonly regulates the cleanup and management of hazardous wastes and substances, referred to as chemicals of concern (COCs), which are released into the environment from regulated commercial and industrial facilities, and on the closure of waste management facility components (e.g., tanks, container storage areas, surface impoundments). TRRP begins to apply on May 1, 2000. However, you may choose to have TRRP apply to your affected property before this date.

Releases of COCs can affect the quality of our air, groundwater, and other environmental media (Figure 1) and may pose unacceptable risks to human health and the environment.

However, when cleaned up to protective levels or properly managed, the releases do not pose unacceptable risk.

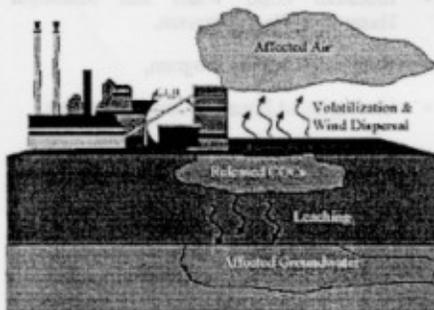


Figure 1. How COCs affect environmental media

The TRRP sets out new requirements for how to determine if releases or closures pose unacceptable risk. If they do, the rule defines requirements for what must be done to reduce the risk, prevent pollution, or protect natural resources.

The purpose of this document is to introduce the new TRRP and provide some basic background information, highlight some important features of the new rule, provide an overview of the applicability of the TRRP, and discuss how to transition to using the new rule.

## Is the TRRP in effect yet?

Yes, TRRP went into effect on September 23, 1999. People can voluntarily use the rule now, but the rule does not have to be applied until May 1, 2000. However, even then the rule does not have to be applied if certain "grandfathering" conditions are met.

## What types of sites does it apply to?

The TRRP applies to releases of COCs into the environment that are produced, stored, or disposed at commercial and industrial facilities or operations. The TRRP also applies to the closure of tanks, landfills, and other waste management facility components at locations that are regulated under any of these programs:

- State Superfund Program,
- Industrial Solid Waste and Municipal Hazardous Waste Program,
- Voluntary Cleanup Program,
- Underground Injection Control Program,
- Wastewater Treatment Program,

Some landfills regulated by the Municipal Solid Waste Program are also covered by the TRRP.

Beginning September 1, 2003, TRRP will also apply to the Petroleum Storage Tank Program.

For more information regarding the applicability of the TRRP, please see *TRRP Applicability and Grandfathering* (RG-366/TRRP-2).

## Why is there a new rule?

This new rule was established for the following reasons:

- To keep pace with the advancement in the science of setting environmental cleanup levels.
- To implement new regulatory flexibility to encourage people to voluntarily address environmental problems.
- To clarify and further develop provisions that were contained within the former rules.
- To create one set of rules that can be universally applied to environmental releases covered under the different TNRCC remediation programs.

## What is regulated under TRRP?

The rule defines the requirements for assessing the extent of the environmental problem, establishing human-health and environmentally protective concentration levels (PCLs), and cleaning up or controlling the environmental problem. The rule also addresses applicability, grandfathering matters, and report filing requirements. Complying with the TRRP rule involves the four key steps illustrated in Figure 2.

In each of these steps you may be required to file related notices, reports, or both. We are in the process of developing detailed guidance documents for each element of these steps. See the table at the end of this document for the tentative date by which each of these guidance documents will be available. This table will be updated on the web at [www.tnrcc.state.tx.us/permitting/trrp.htm](http://www.tnrcc.state.tx.us/permitting/trrp.htm).

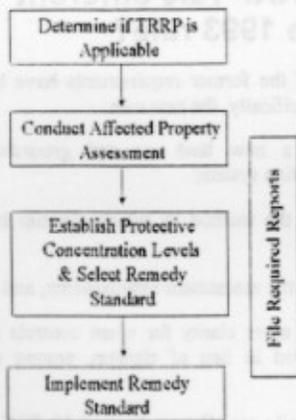


Figure 2. Complying with the TRRP Rule

### Determine Applicability

The process begins with establishing the applicability of the TRRP to a given environmental problem. See the rule and *TRRP Applicability and Grandfathering* (RG-366/TRRP-2) for more information.

### Assess Affected Property

The rule sets out guidelines to adequately assess the extent of any COCs in soil and groundwater, impacts to other environmental media, and the general surface and subsurface conditions at the affected property. As part of the assessment, the land and groundwater affected by the COCs must be classified in accordance with criteria defined in the rule so that proper cleanup levels and cleanup requirements can be established.

For example, the land use, which must be classified as either residential or commercial/industrial, is important because different cleanup levels are established for each of the land uses. More stringent cleanup levels are applied to residential properties than commercial/industrial properties.

Similarly, a groundwater classification system is set in the rule so that the sensitivity and use potential of the groundwater, which is different in different areas of the state, can be considered when setting cleanup levels and cleanup requirements. These new guidelines are different from those set forth in the previous rules. These new rule requirements appear in 30 TAC §§350.51-350.54.

Additionally, as part of the affected property assessment, the rule lists requirements notifying owners of properties that were sampled or affected by COCs and people who may be potentially exposed to levels of COCs that could pose a risk that critical information from the assessment is available. These new notification requirements appear in 30 TAC §350.55.

### Establish PCLs

The rule sets out procedures for calculating cleanup levels that are protective of human health and the environment referred to as protective concentration levels (PCLs) in the rule. The procedures to calculate PCLs are set forth as Tier 1, 2, or 3.

Tier 1 is the simplest and cheapest method to set protective concentration levels, but generally results in the most stringent levels. Tier 3 uses the most sophisticated methods and is likely the most expensive, but it factors in the most site-specific considerations. Because of this, it makes sense to start with Tier 1 and progress to Tier 2 or 3 only when warranted.

On the other hand, under the tiered process for ecological issues, Tier 1 is actually a checklist that determines whether you must move into Tier 2 or 3 to set protective concentration levels.

COCs that are found in concentrations higher than the calculated PCLs must be cleaned up or controlled under one of the two remedy standards established in the rule. These rule requirements appear in 30 TAC §350.71-350.79.

## Implement Remedy Standards

The rule provides two remediation options to address COCs that exceed protective concentration levels: Remedy Standard A and Remedy Standard B. These rule requirements appear in 30 TAC §§350.31-350.33 and §350.37.

- Remedy Standard A is a cleanup option. A person may initiate or "self-implement" Remedy Standard A without seeking prior approval from the TNRCC. However, you must submit a Self Implementation Notice to the TNRCC 10 calendar days before the actual cleanup begins.
- Remedy Standard B provides the option to control and manage the COCs instead of cleaning them up. Under Remedy Standard B, the COCs must be controlled and managed such that their extent does not spread in an unauthorized manner and so that no one will be exposed to COCs at a level above the PCL.

If Remedy Standard B is used, then long term monitoring will most likely be required, financial assurance may be required, and institutional controls (deed notices and restrictive covenants) must typically be filed in the county deed records. Remedy Standard B cannot be self-implemented. A Response Action Plan must be submitted to and approved by the TNRCC before a person can use Remedy Standard B.

### File Reports

The rule defines notices and reports you may have to file at various points in the process. The number and type of notices and reports you must submit depends on whether you choose to self-implement cleanup, the remedy standard selected, and how long the remedy takes to complete.

Small, quickly addressed problems will require fewer reports than a large, complex problem that takes a long time to address. Further, you may combine several reports into a single report when that is most efficient. The report requirements appear in 30 TAC §§350.91-350.96.

## Is the TRRP rule different from the 1993 rule?

Yes, some of the former requirements have been modified. Specifically, the new rule:

- sets up a new land use and groundwater classification system;
- modifies the method by which cleanup levels are set;
- modifies the assessment requirements; and
- provides more clarity for when controls may be allowed in lieu of cleanup, among other things.

For more details see *Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the Shift* (RG-366/TRRP-4), which describes key differences between the TRRP and the 1993 rule.

## If I switch to the TRRP, do I have to start over?

This is a logical question if you have already begun to address a release under the 1993 rule — and no, you will not have to start over. But you may have to do some things differently, perhaps do some additional work, or redo some work to conform with TRRP requirements. If you complied with the assessment requirements of the 1993 rule then you may have adequately addressed the TRRP assessment requirements (the 1993 rule required you to characterize the nature and extent of COCs in excess of background concentrations). However, you must meet the new notification requirements, establish cleanup levels based on the TRRP procedures, and perhaps make some adjustments to comply with the new remedial requirements.

The TNRCC intends that a transition into using the TRRP occur not by starting over, but by completing any additional or remaining work that may be necessary. The degree to which additional work may be needed, if any, depends on the situation.

To determine how changing to the TRRP may affect you, we recommend that you seek the services of an environmental professional. An environmental professional can determine what completed work satisfies the TRRP, determine what additional or remaining work may be necessary, help evaluate the costs and benefits of using Tier 1, 2, or 3 and Remedy Standard A or B, and provide an estimate of the associated cost and time involved in your transition to TRRP.

For more information on the matter, see *Use of Data Collected for 30 TAC 335 under the TRRP* (RG-366/TRRP-5).

## **If I will be using the TRRP, what should I do?**

The TRRP rule does not address the actual reporting of releases of COCs. The reporting requirements you must follow depend on which regulatory program you fall under. When the TNRCC program area determines that the release must be addressed, you are ready to begin using TRRP.

If site work has not already begun under other rules, then you must initiate action to comply with the TRRP. You will have to assess the affected property and establish PCLs to determine the need for any remediation, all in accordance with the requirements of the TRRP.

We recommend that you plan sufficiently before you begin site activity so that you can identify and collect all of the needed information as efficiently as possible. The information needs will depend on whether you establish PCLs under Tier 1, 2, or 3 and whether you plan to use Remedy Standard A or B.

For example, if you collect data to support Tier 1 and Remedy Standard A only, you will likely not have the information needed to calculate protective concentration levels under Tier 2 or 3 or to exercise some of the more flexible options under Remedy Standard B. Be sure and submit a self-implementation notice or response action plan, as appropriate, before you begin a response action to meet Remedy Standard A or B requirements.

If you have already begun work under other rules, then you should determine what additional information you need to comply with the TRRP. Your assigned TNRCC project manager can help you with this determination and other aspects of your transition to the TRRP. Then you should begin to collect this information.

## GENERAL

RG-366	Topic*	Availability*
TRRP-1	Introduction to TRRP	2/00
TRRP-2	Applicability and Grandfathering	2/00
TRRP-3	Compatibility with RCRA	4/00
TRRP-4	Comparison to 30 TAC 335	2/00
TRRP-5	Use of Data Collected for 30 TAC 335	5/00

## AFFECTED PROPERTY ASSESSMENTS

RG-366	Topic*	Availability*
TRRP-6	Planning and Receptor Surveys	4 <sup>th</sup> Qtr 2000
TRRP-7	Landuse Determinations	4 <sup>th</sup> Qtr 2000
TRRP-8	Groundwater Classification	4/00
TRRP-9	Exposure Pathway Evaluations	6/00
TRRP-10	Determining Target COCs	10/00
TRRP-11	Contrasts in Data Needs for Tiers 1, 2 and 3	1/01
TRRP-12	Assessment Requirements (Extent determinations)	4/00
TRRP-13	Validation Requirements for Analytical Data	4/00
TRRP-14	Screening of COCs	4/00
TRRP-15	Determining Representative Concentrations	7/00
TRRP-16	Analytical Testing	4 <sup>th</sup> Qtr 2000
TRRP-17	Notification of Affected Persons	4/00

## DEVELOPMENT OF HUMAN HEALTH PCLs

RG-366	Topic*	Availability*
TRRP-18	Risk Levels and Cumulative Adjustments	1/01
TRRP-19	Toxicity Factors and COC Properties	10/00
TRRP-20	Exposure Factors	1/01
TRRP-21	Determining Points of Exposure	4/00
TRRP-22	Development of Human Health PCLs	8/00
TRRP-23	Correct Use of Tier 1 PCL Tables	3/00
TRRP-24	Determining PCLs for Surface Water and Sediment	8/00
TRRP-25	Determining Critical PCLs	8/00
TRRP-26	Use of Tier 1 and 2 Natural Attenuation Factor Models	9/00
TRRP-27	Development of PCLs for TPH	3/00

## REMEDY STANDARDS

RG-366	Topic*	Availability*
TRRP-28	Application of Remedy Standards to Affected Properties	4/00
TRRP-29	Soil and Groundwater Response Objectives	4/00
TRRP-30	Compliance Sampling and Monitoring	4 <sup>th</sup> Qtr 2000
TRRP-31	Evaluating the Effectiveness of Remedies	4 <sup>th</sup> Qtr 2000
TRRP-32	Demonstrating Sufficient NAPL Recovery	4 <sup>th</sup> Qtr 2000
TRRP-33	Monitored Natural Attenuation Demonstrations	3 <sup>rd</sup> Qtr 2000
TRRP-34	Facility Operations Area	4/01

## STANDARDIZED REPORT FORMS

Form No.	Title	Availability*	Form No.	Title	Availability*
10323/SIN	Self-Implementation Notice	2/00	10327/RAER	Response Action Effectiveness Report	1/01
10324/NOI	Notice of Intent (Grandfathering)	3/00	10328/RACR	Response Action Completion Report	7/00
10325/APAR	Affected Property Assessment Report	5/00	10329/PRACR	Post Response Action Care Report	1/01
10326/RAP	Response Action Plan	7/00	10337/NOIST	Notice of Intent to Switch to TRRP	3/00

\* Topic refers to subject matter, not document title. Availability refers to a target date only. Documents will be issued as completed. Please keep track through the website <http://www.trrc.state.tx.us/permitting/trrp.htm>.

## Does TRRP apply to me?

Generally, TRRP is applicable beginning May 1, 2000 unless you meet exclusion or "grandfathering" conditions which allow you to remain under the rule that had been applicable before TRRP. See Section IV below for details on exclusions and Section V below for conditions for grandfathering.

### II. How to determine TRRP applicability.

To determine if TRRP applies, three basic steps must be completed.

Step 1. - Determine if TRRP potentially applies: Does a permit, enforcement order or rule other than TRRP require a response to a release or a closure of a waste management unit?

Step 2. - Determine if your site is excluded from TRRP. If TRRP applies unless an exclusion from TRRP exists.

Step 3. - Determine if your site is eligible to grandfather. If your site is not excluded, then you may still be able to remain under pre-TRRP requirements (Grandfathering) if certain steps are taken. In some cases these steps need to be taken before May 1, 2000.

The following diagram presents a simplified overview of the steps that need to be followed to determine applicability. For detailed guidance on each of these steps, consult the sections referenced in each step of the diagram.

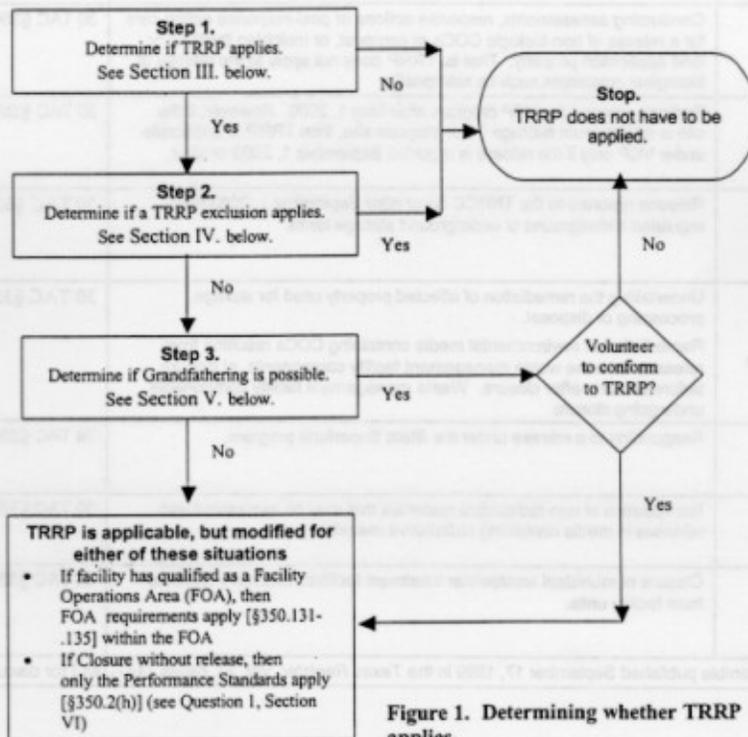


Figure 1. Determining whether TRRP applies.

### III Determine if TRRP applies

TRRP applies when any of the following events at a site (affected property) in any of the following program areas exists on or after May 1, 2000 unless a TRRP exclusion (Section IV) applies or grandfathering (Section V) is possible. Persons may voluntarily apply TRRP prior to May 1, 2000.

TNRCC Program Requiring Initial Response (Citation)	Events	Rule Reference
Spill Prevention and Control [30 TAC §327.3 & 327.5]	Spill reported pursuant to §327.3 <ul style="list-style-type: none"> <li>• Choose to use TRRP for spill response, or</li> <li>• Spill response will take longer than 6 months which is on or after May 1, 2000 &amp; grandfathering hasn't been initiated</li> </ul>	30 TAC §350.2(b)*
Municipal Solid Waste [30 TAC §330 and 40 CFR §257, 258]	Release from solid waste facilities including old or abandoned solid waste sites, transfer stations, waste incinerator, etc.  Release from landfills regulated by 40 CFR Parts 257 and/or 258 are not generally subject to TRRP unless the TNRCC authorizes use of the TRRP to establish an alternative health-based groundwater protection standard.	30 TAC §350.2(c)*
Underground Injection Control [30 TAC §330]	Unauthorized release of COCs from associated tankage and equipment.	30 TAC §350.2(d)*
Composting [30 TAC §332]	Conducting assessments, response actions or post-response action care for a release of non-biologic COCs at compost, or mulching facilities or land application property. That is, TRRP does not apply to the release of biological organisms such as salmonella.	30 TAC §350.2(e)*
Voluntary Cleanup Program [30 TAC §333]	Persons entering the VCP program after May 1, 2000. However, if the site is a Petroleum Storage Tank program site, then TRRP is applicable under VCP only if the release is reported September 1, 2003 or after.	30 TAC §350.2(f)*
Underground and Aboveground Storage Tanks [30 TAC §334]	Release reported to the TNRCC on or after September 1, 2003 from regulated aboveground or underground storage tanks.	30 TAC §350.2(g)*
Industrial Solid Waste and Municipal Hazardous Waste [30 TAC §335]	Undertaking the remediation of affected property used for storage, processing or disposal.  Remediation of environmental media containing COCs resulting from releases from the waste management facility components, at closure, before closure, after closure. Waste management facility components undergoing closure	30 TAC §350.2(h)*
State Superfund [30 TAC §335, Subchapter K]	Responding to a release under the State Superfund program.	30 TAC §350.2(i)*
Radioactive Substance Rules [30 TAC §336]	Remediation of non-radioactive materials that may be associated with releases in media containing radioactive material.	30 TAC §350.2(j)*
Sludge use, Disposal and Transportation [30 TAC §312]	Closure of municipal wastewater treatment facilities that have releases from facility units.	30 TAC §350.2(k)*
*See also the Preamble published September 17, 1999 in the Texas Register, Vol. 24, pages 7441-7442 for discussion.		

TRRP also applies, beginning May 1, 2000, in either of the following events unless either a TRRP exclusion (Section IV) applies or grandfathering (Section V) is possible.

Other	Events	Rule Reference
Other Releases subject to Texas Water Code Chapter 26	Release subject to the Texas Water Code, but only if specifically required by the TNRCC.	30 TAC §350.2 (l) See also the Preamble published September 17, 1999 in the <i>Texas Register</i> , Vol. 24, pages 7442
Substantial Change in Circumstances	If substantial change in circumstances (e.g., evidence of new contamination, selected remedy is not effective) at sites closed under pre-TRRP or TRRP requirements results in an unacceptable risk to human health or the environment. Leaking Petroleum Storage Tank sites closed under 30 TAC 334 that are reopened will be evaluated under 30 TAC 334 standards regardless of when re-opened.	30 TAC 350.35 See also the Preamble published September 17, 1999 in the <i>Texas Register</i> , Vol. 24, pages 7551-7553

#### IV. Determine if a TRRP exclusion applies.

To determine if your site is excluded from TRRP, review these exclusions. If any exclusion applies to your situation, then TRRP does not apply. Complete the cleanup or closure under the rules that were applicable before TRRP. If no exclusions apply, proceed to Section V to determine if your site meets the conditions for grandfathering under pre-TRRP requirements.

- Governmental entities that are not responsible parties conducting remedial actions are not subject to TRRP [§350.4 (a) (64)]
- Injection Wells. Unauthorized releases below the lower - most underground source of drinking water as defined in 30 TAC §331.2 are not subject to TRRP [§350.2(d)] (for example, solution mining reclamation and Class I disposal well excursions below the underground source of drinking water would not be subject to TRRP.)
- Composting. Releases of biologic contaminants into environmental media are not subject to TRRP [§350.2 (e)]
- Radioactive Substances. TRRP does not apply to the radioactive constituents at a site. [§350.2 (j)]
- Reportable spills subject to the spill rules [30 TAC §327] that are remediated in less than 180 days are not subject to TRRP [§350.2(b)]. Cleanup standards for spills remediated in less than 180 days are to be set by the TNRCC Regional Office.
- Municipal Landfills. Landfills regulated under 40 CFR §257/258 are not subject to TRRP, except in limited circumstances if authorized by the TNRCC [§350.2 (c)].
- Leaking Petroleum Storage Tank Sites. Releases from all underground and aboveground storage tanks regulated under 30 TAC §334 are not subject to TRRP unless the release is reported to the TNRCC on or after September 1, 2003.
- Industrial Hazardous and Non-Hazardous Waste/Municipal Hazardous Waste. Facility closures are not required to comply with TRRP if an existing permit or order of the commission for that facility specifies the use of another rule or other performance criteria [§350.2(h)(1)], unless the person obtains authorization from the TNRCC via the appropriate administrative process to apply TRRP.
- Municipal Waste Water Treatment Facility Closures. These closures are not subject to TRRP unless permit requires the TRRP rules to apply. [§350.2 (k)]. The TNRCC will continue to allow municipal

facilities to choose between closing under TRRP or undertaking a site-specific "clean" closure approved by the Water Quality Program.

- No. 3 • State Superfund Sites. In the event of a conflict between TRRP and 30 TAC 335 Subchapter K, TRRP does not apply, to the extent of the conflict. [§350.2 (l)]
- No. 7 • VCP sites. If conflicts exist between TRRP and VCP regulations, the TRRP does not apply to the extent of the conflict. [§350.2(f)] Petroleum Storage Tank (PST) program sites (30 TAC §334) coordinated under the VCP meet the PST exceptions listed in the earlier bullet for the Leaking Petroleum Storage Tank Sites.

## V. Determine if Grandfathering is possible

Even if TRRP would otherwise be applicable, 30 TAC §350.2 (m) of TRRP allows persons several ways to remain under existing (i.e., pre-TRRP) requirements after the applicability date of May 1, 2000. See TNRCC Regulatory Guidance RG-366/TRRP-4 *Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the Shift* for insight into the key differences between TRRP and the 1993 Risk Reduction Rule that may aid in your decision to grandfather or not. Please review the following five questions to determine if you are eligible to grandfather under pre-TRRP requirements. Please note that even if you initially choose to grandfather and later change your mind, you typically will be able to switch to TRRP at that later time. However, please be advised that once you switch to TRRP, you cannot switch back.

### Have you started a response action under Risk Reduction Rule Remedy Standard 1 or 2 before May 1, 2000?

If you started a response action under previous commission rules (i.e., Title 30, Chapter 335, Subchapters A and S, relating to Industrial Solid Waste and Municipal Hazardous Waste in General; Risk Reduction Standards, respectively) before May 1, 2000, and intend to conduct a Risk Reduction Rule Remedy Standard 1 or 2 response action, (§335.8(c)(1) and (2)) relating to closures and remediation (if directed by permit, see the later question concerning TNRCC permits), then you may grandfather and continue under Remedy Standard 1 or 2 provided you meet the following conditions:

- + Provide notification to TNRCC of the person's intent to proceed under Risk Reduction Rule Remedy Standard 1 or 2 prior to May 1, 2000, [30 TAC §335.8(c) and §350.2(m)] and
- + Either receive a written confirmation of receipt of such notice from TNRCC, or, if no TNRCC confirmation is received, submit evidence of such proper and timely notice filing to TNRCC by May 1, 2001. An entry of the notice in a TNRCC tracking system or copy of the notice, together with a copy of the postal meter date or the dated telefax transmittal sheet showing a date prior to May 1, 2000 will be sufficient evidence. Or persons may wish to submit the *Notice of Intent (NOI) [Grandfathering]* form to TNRCC postmarked by April 30, 2000 (see TNRCC Form 10324/NOI), and
- + Submit the final report for Remedy Standard 1 or 2 remediation to the TNRCC by May 1, 2005.

### Have you started a response action under the Risk Reduction Rule before May 1, 2000 and now intend to achieve Risk Reduction Rule Remedy Standard 3?

If you provided notification of your intent to proceed under the Risk Reduction Rule as required by §335.8(c) to the agency before May 1, 2000, then you started a response action and can grandfather under Risk Reduction Rule Remedy Standard 3 to either close or remediate a release (if directed by permit, see the later question concerning TNRCC permits), provided that you submit a remedial investigation report that fully complies with 30 TAC §335.553(b)(1) prior to May 1, 2001 (30 TAC §335.553(b)). The TNRCC will provide some leeway in judging whether a report fully complies with this section; for example, the agency will allow the person to respond to at least one set of NODs after May 1, 2001. 24

Tex. Reg. 7503. Persons may send an optional *Notice of Intent [Grandfathering]* form to TNRCC to confirm continuation of response using Risk Reduction Rule Remedy Standard 3.

#### **Are you under a TNRCC Order?**

If you are continuing a closure or release response under a pre-existing order, the TNRCC will generally grandfather remediation or closures that are being carried out pursuant to a pre-existing order, although excessive delays on the person's part in carrying out the order's provisions could result in enforcement action and a possible loss of the grandfathered status.

#### **Are you under a TNRCC permit?**

If you are continuing a closure under a permit that hasn't been renewed to conform to TRRP, then the closure plans adopted as part of a permit issued prior to May 1, 2000 should be followed until permit renewal. At the time of permit renewal, closure plans that are in process of implementation according to the closure schedule will be grandfathered automatically; they do not need to submit the notices or meet the remedial investigation requirements noted above for Risk Reduction Rule Remedy Standard 1, 2 or 3 grandfathering. Closure plans that have not yet been initiated upon permit renewal will be conformed to TRRP.

#### **Are you closing a RCRA less than 90 day accumulation unit?**

A person can conduct a closure of units not subject to permitting, with or without associated releases under pre-TRRP rules if the provisions of 30 TAC §350.2 (m) are met. These include, for Risk Reduction Rule Remedy Standard 1 or 2 closures, filing a notice of intent prior to May 1, 2000 (and confirming by May 1, 2001 that the TNRCC received the notice in a timely manner) that the closure will proceed under Risk Reduction Rule Remedy Standard 1 or 2 and completing the closure prior to May 1, 2005. For closures under Risk Reduction Rule Remedy Standard 3, submit a fully compliant Remedial Investigation Report prior to May 1, 2001.

## **VI. Frequently asked Questions**

*Question 1: I have a waste management unit that doesn't require a permit (i.e., a <90 day hazardous waste generator accumulation tank or an on-site non-hazardous landfill). How does TRRP impact me?*

*Answer 1:* After May 1, 2000, unless exclusions or grandfathering applies, TRRP will supply the closure performance standards for closure of these units. These standards are contained in 30 TAC §350.2 (h).

- a. For units that don't have a release, TRRP only requires compliance with the following requirements:
  - Close the unit in a manner to minimize or eliminate, to the extent necessary to protect human health and the environment, the post closure escape of waste, contaminants, leachate, run-off or decomposition products to the surrounding environmental media, and
  - The removal, decontamination or control requirements for waste specified in Subchapter B of the TRRP Rules (detailing the requirements for what constitutes removal, decontamination or controls and requiring post closure requirements in the event controls are used).
  - Other requirements of TRRP (e.g., property assessment requirements) will not apply. Also, note that TRRP does not define when a release has occurred or how a release is to be detected—that is left to each program area. Finally, remember that any additional requirements that may be different or more stringent than the applicable requirements for TRRP also will apply (e.g., RCRA hazardous waste requirements).
- b. For units with a release, the full provisions of TRRP will apply to the release.

Note: Persons desiring to close units under pre-TRRP requirements should quickly evaluate whether exclusions or grandfathering applies. For example, units that don't require a permit can currently be closed pursuant to the existing Risk Reduction Rules contained in 30 TAC Chapter 335. To continue a closure under those rules the person must comply with the grandfathering provisions of TRRP contained

in §350.2 (m). These provisions require, for Standard 1 or 2 closures, filing a notice of intent prior to May 1, 2000 (and confirming, by May 1, 2001 that the Agency received the notice in a timely manner) that the closure will proceed under Standard 1 or 2 (the closure must be complete prior to May 1, 2005). For closures under Standard 3, submit a fully compliant Remedial Investigation Report prior to May 1, 2001.

**Question 2:** *If I submit my remedial investigation report under Remedy Standard 3 of the existing Risk Reduction Rules prior to May 1, 2001, but receive notices of deficiency after that date, have I triggered the application of TRRP to my project?*

**Answer 2:** Possibly not. The TNRCC may allow persons to respond to at least one set of notice of deficiencies after the May 1, 2001 grandfather deadline without triggering TRRP. However, the intent is to work with those sites where the remedial investigation is complete, but some information is lacking. The intent is not to extend the grandfathering to those sites where the remedial investigation report is substantially incomplete.

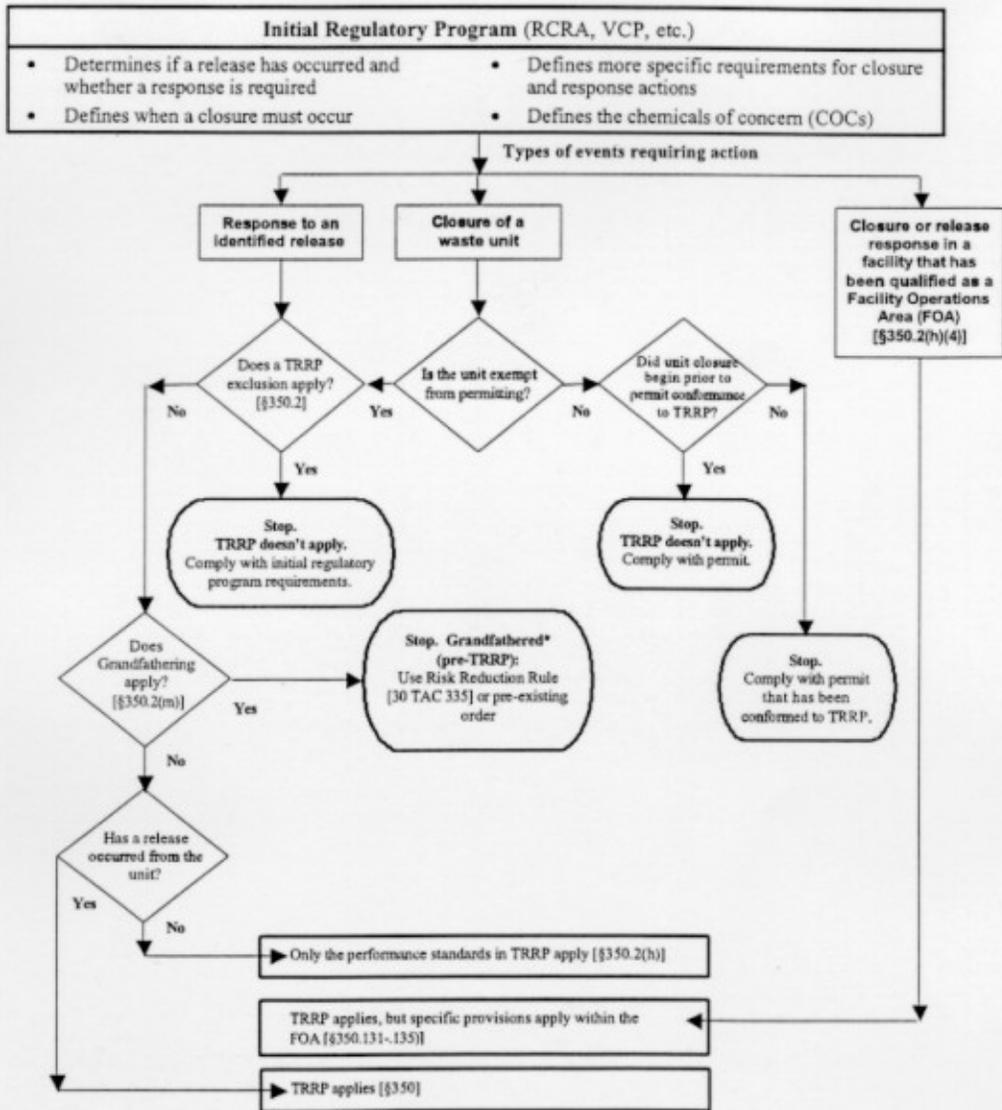
**Question 3:** *If I have a permitted waste management unit with an associated closure plan, will TRRP need to be followed when I close my units?*

**Answer 3:** The intent of the TNRCC is to allow facilities with permitted units to close according to the closure plans that were approved as part of the permit. As a result, if a unit begins closure under a pre-TRRP closure plan, the TNRCC will allow the unit to continue to close under that closure plan and pre-TRRP requirements. However, the TNRCC also intends to incorporate TRRP requirements into permit closure plans during the permit renewal process. Therefore, any closure plans that have not yet been initiated before the permit is renewed will require closure plan revisions conformed to TRRP. As a result, owners and operators of facilities with permits up for renewal should anticipate that TRRP will be applicable to units for which a closure has not yet been initiated.

**Question 4:** *If I have a facility with different releases in different areas being addressed under the old rule, can I grandfather some releases under the old rule and switch some to TRRP?*

**Answer 4:** Yes, each release area or separate problem is judged on its own merit regarding grandfathering and switching to TRRP. For further information, please see TNRCC Regulatory Guidance RG-366/TRRP-5 *Use of Data Collected for 30 TAC 335 under TRRP.*

Figure 2. Flowchart of TRRP Applicability



\*Notes: Infrequently, the Executive Director may require specific releases subject to the Texas Water Code Chapter 26 to comply with TRRP.

Even if grandfathering criteria are met, persons may choose to comply with TRRP. Additionally, if a permit or order does not reference TRRP, persons can seek authorization via the appropriate administrative process to proceed under TRRP.



# TNRCC Regulatory Guidance

Remediation

RG-366/TRRP-4 March 2000 DRAFT

## SUBJECT: **Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the Shift**

**Objectives:** This guidance document summarizes the primary differences between the Risk Reduction Rule and the Texas Risk Reduction Program Rule.

**Audience:** General Public, Regulated Community, and Environmental Professionals

**References:** The regulatory citation for the Texas Risk Reduction Program (TRRP) Rule applicability is 30 TAC 350. The regulatory citation for the Risk Reduction Rule (RRR) is 30 TAC 335.

The TRRP Rule and Preamble as well as the RRR are online at <http://www.tnrcc.state.tx.us/oprd/rules/indxpdf5.html>.

The TRRP Rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350, and was published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). Download Tier 1 PCL Tables, toxicity factors, and other TRRP information at <http://www.tnrcc.state.tx.us/permitting/trrp.htm>.

**Contact:** Technical Support Section at 512/239-0310. Corrective Action Section at 512/239- 2343. Responsible Party Remediation Section at 512/239-2200. Site Assessment & Management Section at 512/239-2509. Superfund Cleanup Section at 512/239-2425. Voluntary Cleanup Program Section at 512/239-5891.

The purpose of this document is to summarize the primary differences between the Risk Reduction Rule (RRR) and the Texas Risk Reduction Program (TRRP) rule. The RRR is located in Subchapters A and S of Chapter 335 (30 TAC 335) and is sometimes referred to as the "old rule" or the "1993 rule." On the other hand, the TRRP rule is located in Chapter 350 (30 TAC 350) and is often referred to as the "new rule" or the "1999 rule."

Our purposes in preparing this document are twofold: First, we summarize points you should consider if the rules allow you to choose between continuing under the RRR—also known as "grandfathering"—and shifting to the TRRP rule. Second, as we compare and contrast the TRRP rule to the rule you already know (the RRR), this document will help you understand the TRRP rule better. Understanding of anything new, like TRRP, can generally be made easier by comparing it with something familiar, like the RRR.

For more information regarding the applicability of TRRP and the circumstances for grandfathering, please see *TRRP Applicability and Grandfathering* (RG-366/TRRP-2). The rule states these circumstances in 30 TAC 350.2(m). Depending upon the circumstances at a

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particular site, either the RRR or TRRP may be the better decision. Knowledge of both rules is necessary in order for a person to make an informed decision regarding which rule to use. This document is not an exhaustive discussion of all of the differences between the RRR and TRRP rules. It is intended, however, to provide sufficient detail to identify and characterize important changes so that you may quickly get a feel for what the implications of TRRP may be. However, to be most successful in making this determination, we recommend that, where appropriate, you seek the services of an environmental professional who is knowledgeable about the requirements of both the RRR and TRRP rules.

## Important Differences Between RRR and TRRP

Topic	RRR (30 TAC 335)	TRRP (30 TAC 350)
<p><b>Site Assessment</b></p>	<ul style="list-style-type: none"> <li>• You must investigate and characterize the horizontal and vertical extent of contaminants to background levels.</li> <li>• Investigation to background is necessary to determine if any land area requires deed certification. (See §§335.554(g), 335.560, and 335.566)</li> </ul>	<ul style="list-style-type: none"> <li>• Rule provides more specific instructions and quality assurance requirements.</li> <li>• You must assess soil laterally to the residential assessment level, as defined at §350.4(a)(3).</li> <li>• For on-site commercial/industrial properties, you may use commercial/industrial levels to focus on-site assessment. However, you must still determine whether the affected property extends off-site at greater than the residential assessment level.</li> <li>• Typically you must assess soils vertically to the higher of background or the method quantitation limit. (See §350.51)</li> </ul>
<p><b>Notification of Analytical Results</b></p>	<p>Rule does not require notification of landowners or other parties of analytical results.</p>	<p>You must provide analytical results to:</p> <ul style="list-style-type: none"> <li>• owners of sampled properties;</li> <li>• owners of properties affected above residential assessment levels;</li> <li>• easement holders for property affected above Tier 1 human health protective concentration levels (PCLs); and</li> <li>• persons exposed above Tier 1 human health PCLs.</li> </ul> <p>(See §350.55)</p>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<p><b>Land Use Classification</b></p>	<ul style="list-style-type: none"> <li>• For Standard 1, land use is not pertinent since cleanup is based upon background.</li> <li>• For Standard 2, land use is based upon definitions for “residential” and “non-residential” property.</li> <li>• For Standard 3, land use is presumed to be residential unless a different land use can be demonstrated considering past, present, and probable future use. (See §335.551, 335.557, and 335.553(b)(2))</li> </ul>	<ul style="list-style-type: none"> <li>• You compare the current land use to the definitions for “residential” and “commercial/industrial” land use.</li> <li>• You use the same land use classification process for Remedy Standards A and B. (See §350.53)</li> </ul>
<p><b>Groundwater Classification</b></p>	<ul style="list-style-type: none"> <li>• Standard 2 specifies that a current or potential source of drinking water will have a naturally occurring background total dissolved solids concentration of less than 10,000 mg/l.</li> <li>• Standard 3 uses the same total dissolved solids criterion for defining a current or potential source of drinking water, but also requires a geologic zone to be sufficiently permeable to transmit water to a pumping well in usable quantities.</li> <li>• Groundwater classification is not used as a basis for allowing exposure prevention approaches. (See §335.559(d)(3) and 335.563(h)(1))</li> </ul>	<ul style="list-style-type: none"> <li>• A detailed classification system for Class 1, 2, and 3 groundwater is provided and is applicable to both Remedy Standards A and B.</li> <li>• Class 1 and 2 groundwater would be a current or potential source of drinking water as that term is used under RRR.</li> <li>• Groundwater response objectives are closely tied to the groundwater class.</li> <li>• A pollution cleanup approach is required for Class 1 groundwater.</li> <li>• A plume management zone, that is, an exposure prevention approach, may be authorized for affected Class 2 or 3 groundwater. (See §350.52)</li> </ul>
<p><b>Ecological Receptors</b></p>	<ul style="list-style-type: none"> <li>• More stringent cleanup levels than human health values will be required, if necessary, to protect ecological receptors.</li> <li>• There is no detailed process provided in the rule as to how and when to perform this evaluation. However, Ecological Risk Assessment guidance is provided which is the same as for the TRRP ecological risk assessment program. (See §335.556(b) and 335.563(j))</li> </ul>	<ul style="list-style-type: none"> <li>• The rule defines a three-tiered approach for evaluating risk to ecological receptors which consists of: <ul style="list-style-type: none"> <li>– Tier 1 – exclusion criteria checklist;</li> <li>– Tier 2 – screening-level ecological risk assessment; and</li> <li>– Tier 3 – site-specific ecological risk assessment.</li> </ul> </li> <li>• You only need to proceed as far through the tiers as is necessary to evaluate ecological risk at a particular affected property. (See §350.77)</li> </ul>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<b>Background</b>	<ul style="list-style-type: none"> <li>• Standard 1 is attained when all contaminants have been removed/decontaminated to background.</li> <li>• Background is always a site-specific determination. (See §335.554)</li> </ul>	<ul style="list-style-type: none"> <li>• Remedy Standards A and B are risk-based and are not based upon the attainment of background.</li> <li>• Background may become the PCL if it is greater than the risk-based PCL.</li> <li>• Background is not necessarily site-specific, as Texas-specific soil background concentrations for metals are provided in Figure: 30 TAC 350.51(m). (See §350.4(a)(6) and 350.51(m))</li> </ul>
<b>Regulatory Approach</b>	<ul style="list-style-type: none"> <li>• Standards 1, 2, and 3 each has a specific process for determining cleanup levels which cannot be used with the other standards.</li> <li>• The cleanup level determination processes are:               <ul style="list-style-type: none"> <li>– Standard 1 – background-based</li> <li>– Standard 2 – specified process and input factors</li> <li>– Standard 3 – site-specific calculations based on guidance</li> </ul> </li> </ul> (See §335.554, 335.556, and 335.563)	<ul style="list-style-type: none"> <li>• PCLs for both Remedy Standards A and B are determined with the same three-tiered process.</li> <li>• The three-tiered TRRP process builds in a step-wise increase in the use of site-specific information.</li> <li>• You decide whether to use:               <ul style="list-style-type: none"> <li>– Tier 1 – generic values;</li> <li>– Tier 2 – site-specific, TNRCC models; and/or</li> <li>– Tier 3 – site-specific, user models.</li> </ul> </li> </ul> (See §350.75)
<b>Institutional Controls Above Background</b>	Standards 2 and 3 require an institutional control, that is, deed certification, whenever a contaminant remains above background. (See §335.560 and 335.566)	<ul style="list-style-type: none"> <li>• Sites restored for residential land use under Remedy Standard A using risk-based PCLs do not require an institutional control.</li> <li>• Standard A commercial/industrial response actions as well as all response actions taken under Remedy Standard B require institutional controls. (See §350.31(g))</li> </ul>
<b>Landowner Consent To Institutional Control</b>	While the rule does not expressly require you to obtain a landowner's consent prior to filing an institutional control, the TNRCC will not approve an institutional control without such landowner's consent.	With limited exceptions explained in §350.111, you must obtain written landowner consent prior to filing a deed notice or Voluntary Cleanup Program certificate of completion in the real property records. (See §350.111(c) and (e))

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<p><b>Use of Institutional Controls</b></p>	<p>Deed certification is the last step in demonstrating to the agency that Standard 2 or 3 has been attained. (See §335.560 and 335.566)</p>	<ul style="list-style-type: none"> <li>• Institutional controls are used for several purposes in addition to noting the completion of a response action.</li> <li>• Example uses of institutional controls include:               <ul style="list-style-type: none"> <li>– notice of the existence and location of a plume management zone (See §350.33(f)(4)(C));</li> <li>– notice when occupational exposure criteria are used as <math>AIR_{RBEL_{inh}}</math> for commercial/industrial land use (See §350.74(b));</li> <li>– notice when a soil exposure area larger than standard size has been approved (See §350.51(l)); and</li> <li>– notice that a long-term response action is being conducted at an affected property (See §350.31(h)).</li> </ul> </li> </ul> <p>(See §350.111)</p>
<p><b>Baseline Risk Assessment</b></p>	<p>For Standard 3, you must prepare a baseline risk assessment which describes the potential adverse effects under both current and future conditions caused by the release of contamination in the absence of any action to control the release. (See §335.553(b)(2))</p>	<ul style="list-style-type: none"> <li>• Baseline risk assessments are not required.</li> <li>• PCLs are back-calculated by determining what concentration of a contaminant could remain at the source and still yield protective concentrations at the point of exposure.</li> </ul>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<p><b>Risk Levels</b></p>	<ul style="list-style-type: none"> <li>• Standard 2 – Cleanup levels are established at:               <ul style="list-style-type: none"> <li>– a risk level of <math>10^{-6}</math> for Class A and B carcinogens;</li> <li>– <math>10^{-5}</math> for Class C carcinogens; and</li> <li>– at a hazard quotient of 1 for noncarcinogens.</li> </ul> </li> <li>• Standard 3 – Cleanup levels are established:               <ul style="list-style-type: none"> <li>– for carcinogens with a goal of <math>10^{-6}</math> but allow less stringent cleanups within a risk range from <math>10^{-8}</math> to <math>10^{-4}</math> based on limited exceptions; and</li> <li>– for noncarcinogens both the hazard quotient and hazard index are not to exceed 1.</li> </ul> </li> <li>• The cumulative risk levels are used to determine whether downward adjustment of cleanup levels is required.</li> </ul> <p>(See §335.558(b), 335.567, 335.563(b) and (c))</p>	<ul style="list-style-type: none"> <li>• A single set of risk levels apply regardless of remedy standard used.</li> <li>• A PCL is established for an individual carcinogen at <math>10^{-5}</math> and the cumulative risk must not exceed <math>10^{-4}</math>.</li> <li>• A PCL is established for an individual noncarcinogen at a hazard quotient of 1 and the hazard index must not exceed 10.</li> <li>• The cumulative risk levels are used to determine whether downward adjustment of PCLs is required.</li> </ul> <p>(See §350.72)</p>
<p><b>Values For Exposure Factors</b></p>	<ul style="list-style-type: none"> <li>• Standard 2 is based on generic exposure factors which cannot be modified.</li> <li>• For Standard 3:               <ul style="list-style-type: none"> <li>– you are required to use standard <i>residential</i> exposure factors unless you document that site-specific data warrant deviation from the standard exposure factors; and</li> <li>– guidance recommends that some of the exposure factors not be changed.</li> </ul> </li> </ul> <p>(See §335.567 and 335.563(e))</p>	<ul style="list-style-type: none"> <li>• §350.74(j) identifies those default exposure factors which may and may not be changed.</li> <li>• §350.74(j)(2) establishes a special process, for commercial/industrial land use only, for changing default values for averaging time for noncarcinogens, exposure duration, and exposure frequency.</li> </ul>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<b>Relevant Exposure Pathways</b>	<ul style="list-style-type: none"> <li>• Standard 2 provides equations for a limited number of exposure pathways and states that cleanup levels for other exposure pathways must be determined, if necessary.</li> <li>• Standard 3 identifies the environmental media of potential concern but provides much less detail regarding exposure pathways.</li> <li>• Procedures for additional pathways/scenarios are provided in guidance. (See §335.556(b), 335.567, and 335.563)</li> </ul>	<ul style="list-style-type: none"> <li>• §350.71(c) specifies those human health exposure pathways for which you must develop PCLs when the exposure pathways are complete or reasonably anticipated to be completed based on the criteria provided.</li> <li>• You shall also evaluate other potentially applicable exposure pathways and develop PCLs for any that are complete or reasonably anticipated to be completed.</li> </ul>
<b>Points of Exposure</b>	<p>Points of exposure must often be determined on a site-specific basis. For example, Standard 3 in §335.563(i)(1) states that soil cleanup levels will be determined “based on human ingestion of the soils at all points where direct contact exposure to soils may occur.”</p>	<p>Locations of the human health points of exposure to environmental media for both on-site and off-site properties are <i>prescribed</i> in §350.37.</p>
<b>Remedy Approval Process</b>	<ul style="list-style-type: none"> <li>• For Standards 1 and 2, you may self-implement a remedy. Agency approval follows completion of the remedy.</li> <li>• For Standard 3: <ul style="list-style-type: none"> <li>– prior approval of the response action by the agency is required; and</li> <li>– you must prepare a <i>corrective measure study</i> which recommends <i>the</i> remedy which <i>best</i> achieves the requirements for remedies.</li> </ul> </li> </ul> <p>(See §335.8(c) and 335.553(b)(3))</p>	<ul style="list-style-type: none"> <li>• For Remedy Standard A, you may self-implement a remedy. Agency approval follows completion of the remedy.</li> <li>• For Remedy Standard B: <ul style="list-style-type: none"> <li>– prior agency approval of the response action is required; however,</li> <li>– you must only demonstrate in the response action plan that the proposed response action will attain the performance objectives.</li> </ul> </li> <li>• No corrective measure study is required. (See §350.32(d) and 350.33(d))</li> </ul>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<b>Cost Consideration</b>	<p>For a Standard 3 remedy, you must:</p> <ul style="list-style-type: none"> <li>• consider capital costs, operation and maintenance costs, and the net present value of operation and maintenance costs as remedy evaluation factors; and</li> <li>• select a <i>cost-effective</i> remedy that achieves the best balance between long-term effectiveness and cost for alternative remedies. (See §335.561(c) and 335.562(g))</li> </ul>	<p>For both Remedy Standards A and B:</p> <ul style="list-style-type: none"> <li>• the consideration of cost is left entirely to you, unless an alternate approach is required by a specific program, such as for a state-funded action. (See §350.4(a)(62) and 350.31(j))</li> </ul>
<b>Exposure Prevention Response Actions</b>	<ul style="list-style-type: none"> <li>• Standards 1 and 2 are “pollution cleanup” not “exposure prevention” remedy standards.</li> <li>• For Standard 3, a remedy must be “permanent or, if that is not practicable, achieve the highest degree of long-term effectiveness possible.”</li> <li>• These requirements strongly favor “pollution cleanup” remedies. (See §335.561(b))</li> </ul>	<ul style="list-style-type: none"> <li>• Remedy Standard A requires “pollution cleanup” response actions.</li> <li>• For Remedy Standard B, any “pollution cleanup” or “exposure prevention” response action, which can attain the relevant performance standards within a reasonable timeframe would be acceptable.</li> <li>• These requirements provide greater flexibility to use “exposure prevention” response actions.</li> </ul>
<b>Groundwater Exposure Prevention Approach</b>	<p>For Standard 3:</p> <ul style="list-style-type: none"> <li>• a groundwater exposure prevention approach is built into the concept of an alternate concentration limit (ACL), as presented at §335.563(h)(2);</li> <li>• ACLs are restricted to commercial/industrial land use and groundwater plume expansion is not allowed;</li> <li>• approval of the ACL is not tied to groundwater classification; and</li> <li>• minimal criteria are provided by which to determine whether to grant approval of such an option.</li> </ul>	<p>For Remedy Standard B:</p> <ul style="list-style-type: none"> <li>• a groundwater exposure prevention approach is built into the concept of a plume management zone (PMZ), as defined in §350.33(f)(4);</li> <li>• a PMZ may be used with either commercial/industrial or residential land use;</li> <li>• limited plume expansion may be allowed in a PMZ;</li> <li>• PMZs are restricted to affected Class 2 and 3 groundwater; and</li> <li>• the groundwater classification system and criteria are provided for evaluating whether such an alternative is appropriate for a site.</li> </ul>

Topic	RRR Rule (30 TAC 335)	TRRP (30 TAC 350)
<b>Financial Assurance</b>	The rule does not require you to provide financial assurance for post-closure care.	For Remedy Standard B: <ul style="list-style-type: none"> <li>• you must provide financial assurance as specified at §350.33(1) for post-response action care whenever physical control measures are used to address soil or groundwater protective concentration level exceedence zones; and</li> <li>• criteria are provided at §350.33(i) for determining when you can terminate post-response action care and cancel the associated financial assurance.</li> </ul>

## What Else is Different About TRRP?

### Revised Methods for Determining Clean Up Levels

- The equations to determine cleanup levels are different in TRRP than the RRR. (See Figure 30 TAC §350.75(b)(1))
- To evaluate the risk presented by the inhalation of carcinogenic chemicals of concern, under TRRP, the inhalation unit risk factor (URF) was used rather than the inhalation cancer slope factor (SF). And for noncarcinogens, the reference concentration (RfC) was used rather than the inhalation chronic reference dose (RfD). However, the URF and RfC are used for the RRR in guidance for Standard 3.
- Where relevant for chemicals of concern, TRRP specifies by equation, for the first time in the rule itself, the manner in which above ground and below-ground vegetables will be considered when determining surface soil cleanup levels (PCLs).
- For TRRP, a surface soil PCL is determined based upon the combined exposure from inhalation (Inh); ingestion (Ing); dermal contact; and, for residential land use, vegetable ingestion. (See Figure: 30 TAC §350.75(b)(1))
- You may not be required to establish a soil leachate-to-groundwater PCL if a demonstration can be made with appropriate soil and groundwater monitoring data that the soils will attain the required response objectives. (See §350.75(i)(7)(C))
- The PCL equation for the soil-to-groundwater exposure pathway that is used in TRRP is more technically appropriate than the 100 times multiplication factor used in the RRR.
- The TRRP rule discusses in detail (See §350.75(i)(4)) how PCLs based upon groundwater discharge and dilution in surface water shall be determined.

### Revised Definitions

- The definitions of surface and subsurface soils are different under TRRP than the RRR. In general, under TRRP, surface soils are the upper 15 feet of soil for residential land use and the upper 5 feet of soil for commercial/industrial land use.
- The TRRP rule contains a definition for groundwater-bearing unit "as a saturated geologic formation, group of formations, or part of a formation which has a hydraulic conductivity equal to or greater than  $1 \times 10^{-5}$  centimeters/second." Groundwater resource classification applies only to groundwater-bearing units.

### New Approach: "Facility Operations Area"

- Subchapter G of TRRP describes a facility operations area (FOA), or site-wide approach, to address multiple sources of chemicals of concern within an operational and permitted chemical or petroleum manufacturing plant. The FOA approach allows facilities to prioritize interim cleanups and to defer final cleanups for the operational life of the facility.

### New QA/QC Requirements

- The performance-based quality assurance/quality control requirements for data acquisition and reporting are established in §350.54 of TRRP.

### Revised Remedy Requirements

- Under TRRP the point of exposure for a plume management zone can be dependent upon whether a property is subject to zoning or a governmental ordinance which is equivalent to the deed notice or restrictive covenant that otherwise would have been required. (See §350.37(1)(3) and (4))
- TRRP at §350.36 describes the requirements which apply when a person relocates soils for reuse purposes from an affected property which is undergoing or has completed a response action and the soils contain chemicals of concern above background.
- The TRRP rule does not specify a particular statistical procedure which has to be used to determine whether a response action is required or whether a remedy standard has been attained. Rather, any statistical procedure can be used which is capable of meeting the performance requirements specified in §350.79(2).

### Revision to No Further Action Determinations

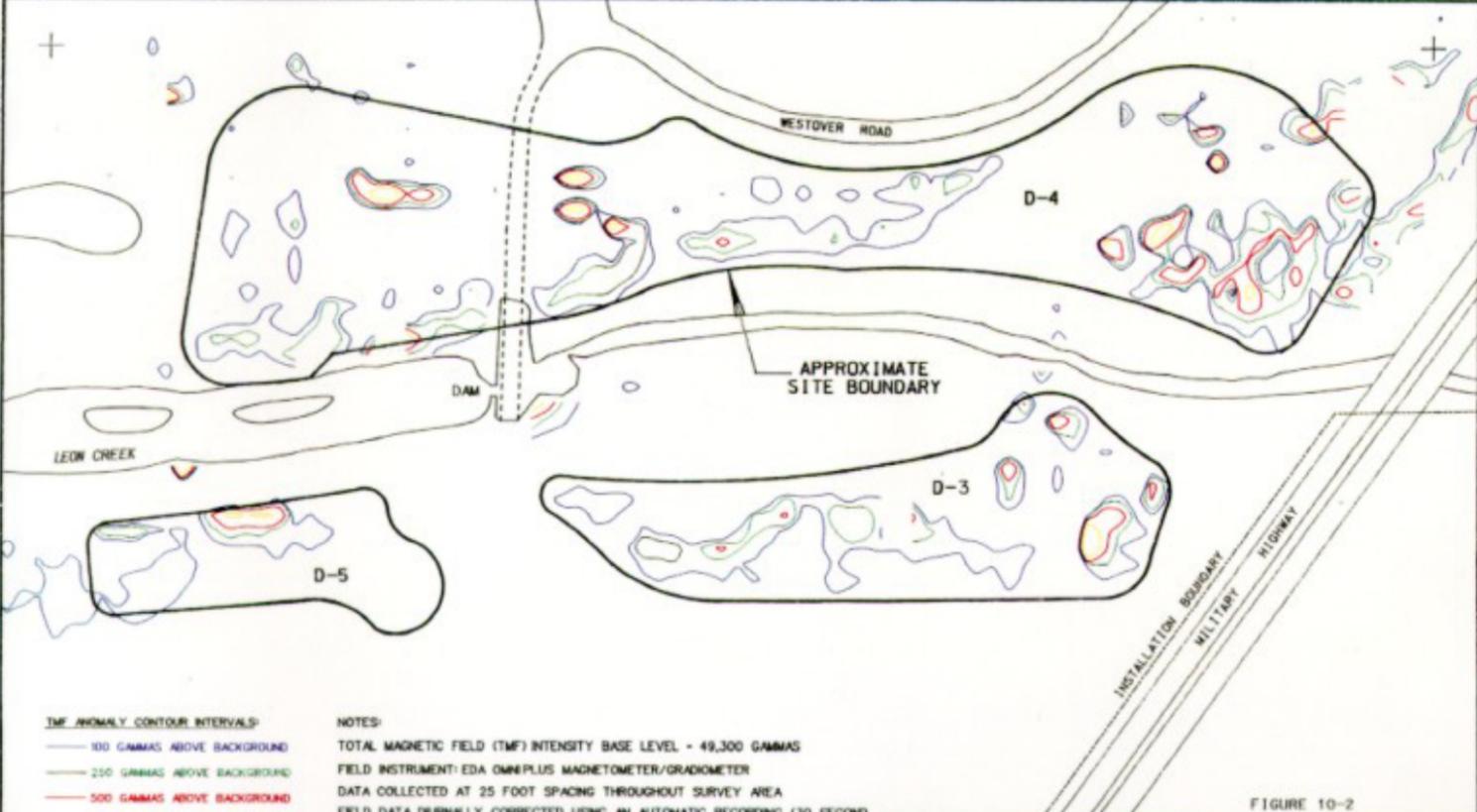
- Under TRRP Remedy Standard B, persons will initially receive a conditional "no further action" letter. This letter will indicate that the person has conditionally completed response actions at a property but must perform post-response action care obligations throughout any initial and any continuing post-response action care period. A final no further action letter will be issued subsequent to termination of the post-response action care period by the executive director. (See §350.34)

**APPENDIX F**  
**VOC ANALYTICAL RESULTS**

**APPENDIX G**  
**MAGNETIC ANOMALIES**

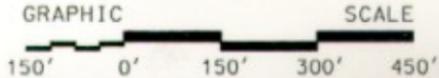
6473914

10-4



- TMF ANOMALY CONTOUR INTERVALS:**
- 100 GAMMAS ABOVE BACKGROUND
  - 250 GAMMAS ABOVE BACKGROUND
  - 500 GAMMAS ABOVE BACKGROUND
  - 1000 GAMMAS ABOVE BACKGROUND

**NOTES:**  
 TOTAL MAGNETIC FIELD (TMF) INTENSITY BASE LEVEL - 49,300 GAMMAS  
 FIELD INSTRUMENT: EDA OMNIPUS MAGNETOMETER/GRADIOMETER  
 DATA COLLECTED AT 25 FOOT SPACING THROUGHOUT SURVEY AREA  
 FIELD DATA DIURNALLY CORRECTED USING AN AUTOMATIC RECORDING (30 SECOND INTERVAL) BASE STATION: EDA OMNIPUS MAGNETOMETER  
 DATA ACQUIRED: JULY-AUGUST, 1989



INSTALLATION BOUNDARY  
 MILITARY HIGHWAY

FIGURE 10-2

	<b>TITLE</b> TOTAL MAGNETIC FIELD DATA, D-4 AREA ZONE 1 REMEDIAL INVESTIGATION REPORT KELLY AIR FORCE BASE	
	<b>FILE NO.</b> 147MG093	<b>DATE</b> 9-6-91