FEASIBILITY STUDY
Jones Road Groundwater Plume
Federal Superfund Site (SUP075)
Harris County, Texas

Shaw Project No. 137226

Prepared for:

Texas Commission on
Environmental Quality
Superfund Section
Remediation Division
12100 Park 35 Circle
Austin, Texas 78753

Prepared by:

Shaw Environmental, Inc.
1401 Enclave Parkway, Suite 250
Houston, Texas 77077

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Table of Contents

List of Figures v
List of Tables v
List of Appendices v
List of Acronyms vi
1.0 Introduction 1-1
1.1 Purpose and Organization of Report 1-1
1.2 Background Information 1-2
1.2.1 Site Description 1-3
1.2.1.1 Site Geology 1-4
1.2.1.2 Site Hydrogeology 1-5
1.2.2 Site History 1-5
1.2.2.1 Previous Investigations 1-5
1.2.2.2 Waste Type and Estimated Quantities of Source Materials 1-6
1.2.2.3 Waste Physical and Chemical Characteristics 1-7
1.2.3 Soil 1-7
1.2.3.1 Soil as a Potential Pathway 1-7
1.2.3.2 Nature and Extent of Soil Contamination 1-8
1.2.3.3 Soil Impact to Human or Environmental Receptors 1-9
1.2.4 Groundwater 1-9
1.2.4.1 Groundwater as a Potential Pathway 1-9
1.2.4.2 Nature and Extent of Groundwater Contamination 1-9
1.2.4.3 Groundwater Impact to Human or Environmental Receptors 1-13
1.2.5 Surface Water and Sediments 1-14
1.2.5.1 Pathway and Location(s), of Contaminant Entry to Surface Waters 1-14
1.2.5.2 Nature and Extent of Sediment Contamination 1-14
1.2.5.3 Contaminated Sediment Impact to Human or Environmental Receptors 1-14
1.2.6 Air 1-14
1.2.6.1 Air as a Potential Pathway 1-14
1.2.6.2 Nature and Extent of Indoor Air Contamination 1-15
1.2.6.3 Contaminated Air Impact to Human or Environmental Receptors 1-15
1.2.7 Exposure Pathways 1-15
1.2.7.1 TRRP Groundwater Classification 1-16
1.2.7.2 Source Area TRRP Groundwater Classification 1-17
1.2.8 Contaminant Fate and Transport 1-17
1.2.9 Baseline Risk Assessment 1-18
1.2.9.1 Groundwater 1-18
1.2.9.2 Indoor Air 1-19
1.2.9.3 Environmental Evaluation 1-19
2.0 Identification and Screening of Technologies 2-1
2.1 Introduction 2-1
2.2 Remedial Action Objectives 2-1
2.2.1 Contaminants of Interest 2-2
2.2.2 Allowable Exposure Based on Risk Assessment 2-2

2.2.3 ARARs 2-2
2.2.3.1 Federal ARARs 2-3
2.2.3.2 State ARARs 2-4
2.2.3.3 Local ARARs 2-4
2.2.4 Development of Remediation Goals 2-4
2.3 General Response Actions 2-5
2.3.1 Soil – Source Area 2-5
2.3.2 Groundwater – Source Area 2-6
2.3.3 Groundwater – Areas West of Jones Road 2-6
2.3.4 Groundwater – Areas East of Jones Road 2-7
2.4 Identification and Screening of Technology Types and Process Options 2-7
2.4.1 Identification and Screening of Soil Technologies 2-8
2.4.2 Identification and Screening of In Situ Groundwater Technologies 2-8
2.4.3 Identification and Screening of Ex Situ Groundwater Technologies 2-9
2.5 Evaluation of Technologies and Selection of Representative Technologies 2-9
2.5.1 Soil Vapor Extraction (SVE) 2-9
2.5.2 Ex Situ Thermal Desorption 2-11
2.5.3 Ex Situ Incineration 2-12
2.5.4 Excavation and Disposal 2-12
2.5.5 Bioremediation (In Situ Groundwater) 2-13
2.5.6 Chemical Oxidation (In Situ Groundwater) 2-13
2.5.7 Monitored Natural Attenuation (In Situ Groundwater) 2-14
2.5.8 Containment (Groundwater) 2-16
2.5.9 Air Stripping (Ex Situ Groundwater) 2-17
2.5.10 Granulated Activated Carbon (Ex Situ Groundwater) 2-17
2.5.11 Chemical Oxidation (Ex Situ Groundwater) 2-18
2.5.12 Ultraviolet Oxidation (Ex Situ Groundwater) 2-18
2.5.13 Aerobic Biological Reactors (Ex Situ Groundwater) 2-19
3.0 Development of Alternatives 3-1
3.1 Selecting Technologies 3-2
3.1.1 Soil Technologies 3-2
3.1.2 In Situ Groundwater Technologies 3-3
3.1.3 Ex Situ Groundwater Technologies 3-4
3.2 Alternatives Developed 3-4
3.3 Detailed Analysis of Alternatives 3-5
3.3.1 Alternative 1 – No Further Action 3-5
3.3.1.1 Description 3-5
3.3.1.2 Detailed Analysis 3-5
3.3.2 Alternative 2 – In Situ Treatment 3-5
3.3.2.1 Description 3-5
3.3.2.2 Detailed Analysis 3-6
3.3.3 Alternative 3 – Hydraulic Containment/Pump and Treat 3-7
3.3.3.1 Description 3-7
3.3.3.2 Detailed Analysis 3-8
3.3.4 Alternative 4 – In Situ Enhancements to Pump and Treat 3-10
3.3.4.1 Description 3-10
3.3.4.2 Detailed Analysis 3-10

4.0 Detailed Analysis of Alternatives 4-1
4.1 Evaluation Criteria 4-1
4.2 Individual Analysis of Alternatives 4-4
4.2.1 Alternative 1 – No Further Action 4-4
4.2.1.1 Description 4-4
4.2.1.2 Assessment 4-4
4.2.2 Alternative 2 – In Situ Treatment 4-5
4.2.2.1 Description 4-5
4.2.2.2 Assessment 4-5
4.2.3 Alternative 3 – Hydraulic Containment/Pump and Treat 4-6
4.2.3.1 Description 4-7
4.2.3.2 Assessment 4-7
4.2.4 Alternative 4 – In Situ Enhancements to Pump and Treat 4-8
4.2.4.1 Description 4-8
4.2.4.2 Assessment 4-8
4.3 Comparative Analysis 4-9
4.3.1 Overall Protection of Human Health and the Environment 4-9
4.3.2 Compliance with ARARs 4-10
4.3.3 Long Term Effectiveness and Permanence 4-10
4.3.4 Reduction of TMV through Treatment 4-11
4.3.5 Short Term Effectiveness 4-11
4.3.6 Implementability 4-12
4.3.7 Costs 4-12
4.4 Summary 4-12
5.0 Bibliography 5-1

List of Figures

Figure 1 Vicinity Map
Figure 2 Site Location Map
Figure 3 Residential Wells and Restriction Areas
Figure 4 Cross Section A-A'
Figure 4A Type Log
Figure 5 Cross Section B-B'
Figure 6 Cross Section C-C'
Figure 7 Potentiometric Surface Map
Figure 8 Sample Locations
Figure 9 PCE Distribution in Soils <50 Feet bgs
Figure 10 PCE Distribution in Groundwater <50 Feet bgs
Figure 11 PCE Distribution in Groundwater <200 Feet bgs
Figure 12 PCE Distribution in Groundwater 200 to 230 Feet bgs
Figure 13 PCE Distribution in Groundwater 231 to 260 Feet bgs
Figure 14 PCE Distribution in Groundwater 261 to 300 Feet bgs
Figure 15 PCE Distribution in Groundwater 300 to 535 Feet bgs
Figure 16 Area of Institutional Controls
Figure 17 Alternative 2: In Situ Treatment Measures
Figure 18 Alternative 3: Hydraulic Containment/Pump and Treat
Figure 19 Alternative 4: In Situ Enhancements to Pump and Treat

List of Tables

Table 1 Chronology of Site Investigations and Significant Events
Table 2 Potential Applicable or Relevant and Appropriate Requirements (ARARs)
Table 3 General Description of Remedial Alternatives and Overview of Basis of Cost Estimate
Table 4 List of Wells Proposed for Groundwater Monitoring
Table 5 Comparative Analysis of Remedial Alternatives
Table 6 Quarterly PCE Groundwater Sampling Results – May 2003 through February 2008

List of Appendices

Appendix A Final Treatability Study Report
Appendix B Simple Capture Zone Modeling
Appendix C Cost Estimates
Appendix D Mass Estimates
Appendix E Water Usage

List of Acronyms

°C	degrees Celsius
AEC	Associated Environmental Consultants, Inc.
AMN	ammonia nitrogen
ARAR	applicable or relevant and appropriate requirements
AWS	annual waste summary
Bell facility	Bell Dry Cleaners facility
bgs	below ground surface
BLRA	baseline risk assessment
BOD	biochemical oxygen demand
BR	Bureau of Reclamation
CEI	Compliance Evaluation Investigation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COCs	constituents of concern
COD	chemical oxygen demand
COPC	constituents of potential concern
CPT	cone penetrometer technology
CRQL	contract required quantitation limit
CSM	conceptual site model
CTE	central tendency exposure
DCE	cis-1,2-dichloroethylene
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DPT	direct-push technology
ESTCP	Environmental Security Technology Certification Program
FS	feasibility study
Finch's	Finch's Gymnastics USA and Childcare Facility
FM	Farm to Market road
ft/day	feet per day
ft/ft	feet per foot
ft^2	square feet
ft/yr	ft per year
GAC	granular activated carbon
Geo-Tech	Geo-Tech Environmental, Inc.
g/cm^3	grams per cubic centimeter
gpm	gallons per minute
HCFCD	Harris County Flood Control District
HI	Hazard Index
HSA	hollow stem auger
ISCO	In Situ chemical oxidation
ITRC	Interstate Technology and Regulatory Council
kg	kilogram

LDEQ	Louisiana Department of Environmental Quality
MCL	maximum contaminant level
µg/m³	micrograms per cubic meter
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mm Hg	millimeters of mercury
MNA	monitored natural attenuation
MUD	municipal utility district
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NOR	notice of registration
NOV	notice of violation
NPV	net present value
O&M	operations and maintenance
ORP	oxidation/reduction potential
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCE	perchloroethylene also known as tetrachloroethylene
PCL	protective concentration level
POTW	publicly-owned treatment works
PQL	practical quantitation limit
PRG	preliminary remediation goals
PST	petroleum storage tank
PWS	public water supply
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RME	reasonable maximum exposure
ROI	radius of influence
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
Shaw	Shaw Environmental and Infrastructure, Inc.
SK	Safety-Kleen Systems
SVE	soil vapor extraction
SVOCs	semi-volatile organic compounds
TAC	Texas Administrative Code
TBC	to-be-considered
TCE	trichloroethylene
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
TDLR	Texas Department of Licensing and Regulation
TDS	total dissolved solids
The Jones Road site	Jones Road Groundwater Plume Federal Superfund Site
TKN	total kjeldahl nitrogen
TMV	toxicity, mobility, or volume
TNRCC	Texas Natural Resource Conservation Commission
TOC	total organic carbon

TRRP	Texas Risk Reduction Program
TSS	total suspended solids
TWC	Texas Water Commission
USC	United States Code
USEPA	United States Environmental Protection Agency
UV	ultraviolet
VC	vinyl chloride
VCP	Voluntary Cleanup Program
VOCs	volatile organic compounds
WBU	water bearing unit
ZVI	zero valent iron

1.0 Introduction

This report presents the results of the Feasibility Study (FS) conducted for the Jones Road Groundwater Plume Federal Superfund Site (the Jones Road site), located in Harris County, Texas. The FS was conducted pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), 42 United States Code (USC), Section 9601 et. Seq., and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), and 40 Code of Federal Regulations (CFR), Part 300.

The FS was conducted based on information presented in the *Final Remedial Investigation Report* (RI) (Shaw, February 2009), the determination of risk documented in the *Baseline Risk Assessment* (BLRA) (Shaw, August 2008), the *Final Treatability Study Report* (Shaw, October 2007) (**Appendix A**), the *Simple Capture Zone Modeling* report (Shaw, July 2009) (**Appendix B**), and Cost Estimates (**Appendix C**). The identification and screening of alternatives retained for detailed analysis have been accomplished, when applicable, using the presumptive remedy approach as directed by the U.S. Environmental Protection Agency (USEPA). The USEPA's *Guidance for Conducting Remedial Investigations/Feasibility Studies under CERCLA* (USEPA, 1988) was also used during the development of this report.

1.1 Purpose and Organization of Report

The FS was conducted to identify and evaluate appropriate methods for controlling concentrations of site-related compounds documented in the affected environmental media associated with the Jones Road site. To provide for the development of appropriate response actions, the FS establishes Remedial Action Objectives (RAOs), defines specific Preliminary Remediation Goals (PRGs), to meet the RAOs, and provides detailed analysis of appropriate remedial alternatives described under the presumptive remedy approach.

Under CERCLA, Superfund remedial actions are designed to satisfy the following requirements:

- Protect human health and the environment;
- Comply with applicable or relevant and appropriate requirements (ARARs) of Federal, State, and local environmental laws within a reasonable timeframe;
- Be cost-effective;
- Use the presumptive remedy approach where appropriate and applicable to develop permanent solutions to the maximum extent practicable;
- Satisfy the preference for treatment that reduces contaminant toxicity, mobility, or volume (TMV).

This report is divided into four primary sections, which are identified and described below.

Section 1.0 Introduction – This section presents an overview of available background information including a description and history of the Jones Road site, site geologic and hydrogeologic conditions, the nature and extent of contamination, discussion of fate and transport of site contaminants, and a summary of human health risks.

Section 2.0 Identification and Screening of Technologies – This section provides a discussion of the applicability and review of the presumptive remedy technologies. It provides an overview of the development of RAOs for each medium of interest, a description of the ARARs associated with the Jones Road site, development of remediation goals and general response actions that describe the estimation of volumes or areas to which remedial technologies may be applied.

Section 3.0 Development and Screening of Alternatives – This section assembles possible remedial technologies into alternatives that achieve some or all of the remedial action goals and provides a range of levels of remediation and a corresponding range of costs.

Section 4.0 Detailed Analysis of Alternatives – This section provides a detailed analysis of the remedial alternatives. The alternatives are evaluated based on their overall protection of human health and the environment, compliance with ARARs, long term effectiveness, reduction of toxicity, mobility, or volume, short term effectiveness, implementation, and cost.

Section 5.0 Bibliography – Contains references to materials used in creating the FS.

Tables – This section contains various tables of data assembled for the FS.

Figures – This section contains figures created to display information needed for the FS.

Appendices – This section contains additional documents used in the creation of the FS.

1.2 Background Information

The RI report (Shaw, February 2009) focused on a contaminated groundwater plume originating from the former Bell Dry Cleaners facility (Bell facility) located within the Cypress Shopping Center at 11600 Jones Road, Harris County, Texas. The plume of contaminated groundwater migrated to drinking water aquifers below adjacent residential and commercial areas. Collectively, the investigation area is known as the Jones Road Groundwater Plume Federal Superfund Site, herein referenced as “the Jones Road site”. The contaminated groundwater plume contains perchloroethylene (PCE; also known as tetrachloroethylene). PCE is a manufactured chemical that is widely used for dry cleaning of fabrics. Major degradation products of PCE, including trichloroethylene (TCE), cis-1,2-dichloroethylene (DCE), trans-1,2-

DCE, and vinyl chloride (VC) have been detected in soil samples taken from the former Bell facility, and groundwater samples taken from the groundwater plume.

1.2.1 Site Description

The Jones Road site lies in the northwest portion of Harris County, Texas, as illustrated on the Vicinity Map (**Figure 1**). The former Bell facility is located within the Cypress Shopping Center at 11600 Jones Road, approximately one-half mile north of the intersection of Jones Road and FM 1960 (Jackrabbit Road), outside the city limits of northwest Houston, in Harris County, Texas, as shown on the Site Location Map (**Figure 2**).

Locally, the area is characterized by residential, commercial, and light industrial development. Residential development has been active since the 1960s effectively eliminating wildlife habitat from the area. Jones Road is the principal north-south corridor through the area, and FM 1960 (approximately one-half mile to the south) provides a southwest-northeast corridor. Commercial development is dominant along Jones Road with residential and limited commercial development along the side streets. Cypress Creek is located approximately one mile to the northwest of the subject area, and White Oak Bayou is located approximately 3,500 feet to the south.

Homes in the area have private water supply wells, and some homes share a single well with others. However, a water line funded by the USEPA and the TCEQ was installed in the area to provide a safe source of drinking water to the community. Approximately 51% of the well owners agreed to discontinue use of their water wells and begin using water from the water line. The water line connections were completed in November 2008. However, participation in the government-funded water line project was voluntary, and about 49% of the well owners declined to participate in the water line project and continue to use their private water wells. Septic systems in the area are used in the absence of a publicly-owned treatment works (POTW) infrastructure.

Permits from the Harris County Subsidence District are required for the installation of new public water supply (PWS) wells and larger wells that could contribute to subsidence. Harris County has designated a limited area around the Jones Road site as an area of "No New Wells", in a contaminated plume area designated by the USEPA and TCEQ (Harris County, 2007). In addition, the Texas Department of Licensing and Regulation (TDLR) has designated a restricted water well drilling area around the Jones Road site (TDLR, 2003). In this area, any new well installed in the restricted area must be drilled to a greater depth, and specific construction methods must be used to prevent cross-contamination. The Harris County delineated "No New Wells" area supersedes the TDLR restricted area. Both the "No New Wells" area and the drilling restriction area are shown on **Figure 3**. The areas do not overlap exactly, but both are large enough to entirely contain the groundwater plume.

1.2.1.1 Site Geology

Site-wide cross-sections and the *Source Area Conceptual Site Model* (Shaw, May 2008), indicate that the subsurface geology was deposited in a fluvial depositional environment, as shown by discontinuous silt and sand units deposited under high to medium energy flow regimes, and thick clay units deposited under low energy flow regimes. The Jones Road site is generally underlain by high plasticity clay (CH) from the ground surface to a depth of approximately 20 feet below ground surface (bgs). An interbedded zone consisting of sand (SP), silt (ML), and silty clay (CL), underlies the high plasticity clay, and extends from a depth of approximately 20 feet to 35 feet bgs. The interbedded zone appears to be laterally continuous at the Jones Road site. High plasticity clay underlies the interbedded zone, and extends from a depth of approximately 35 feet to 60 feet bgs. The high plasticity clay includes randomly distributed discontinuous sand lenses comprising less than ten percent of the high plasticity clay zone. A thick major sand (SP) unit was encountered while installing soil boring RS-1, which extended from a depth of approximately 60 feet to 107 feet bgs (bottom of boring RS-1). Cross section A-A' through the source area, showing the subsurface geology to a maximum depth of 107 feet, is shown on **Figure 4**.

The subsurface geology for the Jones Road site (not just the source area) generally consists of silts and clays within the upper 60 feet of soils, with some thin sand lenses approximately 20 to 30 feet bgs. A well developed sand zone occurred from approximately 60 to 110 feet bgs and was dominant across the Jones Road site, but thinned to the north in monitor wells MW-15 and MW-16. Clay with minor sand lenses were encountered from approximately 110 to 150 feet bgs. A sand unit underlies the clay and extends from approximately 150 to 190 feet bgs. Below the sand lies another clay unit from approximately 190 to 205 feet bgs, which is underlain by another sand unit from 205 to 230 feet bgs. The next clay unit extends from approximately 230 to 260 feet bgs, and the clay is underlain by sand from approximately 260 to 295 feet bgs where the Chicot Aquifer screen intervals occur. A clay unit extends from approximately 295 to 410 feet bgs, where the suspected top of the Evangeline Aquifer exists. A type log showing the general relationship of sand and clay units is presented in **Figure 4A**. However, the stratigraphy at individual wells is highly variable and rarely matches this generalized progression exactly.

Two stratigraphic cross sections were prepared using geophysical well logs obtained during installation of the deep monitor wells at the Jones Road site (deepest well to approximately 430 feet bgs), and from deep municipal water wells drilled into the Evangeline Aquifer (deepest well to approximately 1,845 feet bgs). These two stratigraphic cross sections represent the geology of the deeper zones where the main groundwater plume is found. **Figure 5** presents cross section B-B' running northeast to southwest across the Jones Road site. **Figure 6** presents cross section C-C' running northwest to southeast across the Jones Road site.

1.2.1.2 Site Hydrogeology

The two major aquifers that comprise the water bearing units (WBUs) at the Jones Road site are the Chicot Aquifer and the Evangeline Aquifer. The Chicot Aquifer is the youngest aquifer and it outcrops at the Jones Road site. Most of the water wells at the Jones Road site are screened in the Chicot Aquifer. The Evangeline Aquifer underlies the Chicot Aquifer, beginning at approximately 400 feet bgs at the Jones Road site, and is mainly tapped by local municipal utility districts (MUD). Hydraulic conductivity values in Harris County range from 14 to 35 feet per day (ft/day) for the Chicot Aquifer (Young et al., 2006), and 20 to 100 ft/day for the Evangeline Aquifer (LDEQ, 2003). Hydraulic conductivity measurements reported in the RI for source area soil samples from the first WBU ranged from 0.008 to 0.0042 ft/day.

Groundwater in these aquifers generally flows from the northwest to the southeast. Groundwater flow directions at the Jones Road site reported in the RI were to the south or southeast. For five water wells (173 to 210 feet bgs) the measured flow direction was to the south with a gradient of 0.011032 feet per foot (ft/ft). For the ten deep monitor wells (294 to 357 feet bgs) the measured flow direction was to the southeast with a gradient ranging from 0.00248 to 0.00267 ft/ft (see **Figure 7**).

1.2.2 Site History

The Cypress Shopping Center was constructed in 1984, and it is believed that the Bell facility began dry cleaning operations sometime in 1988. The Texas Water Commission (TWC) issued a Notice of Registration for Solid Waste Management to the Bell facility in 1988 and the permit continued through May 2002 before the dry cleaning operations were shut down. The Bell facility was reported to use at least one dry cleaning machine along with conventional laundry equipment. As part of the recovery process, water and other contaminants were removed by a water separator and drained out of the machine on a continuous basis into a 5-gallon plastic bucket. The drained liquid was then discharged into a steam-heated ceramic pot to evaporate the liquid. The pot was vented through the rear wall of the facility directly to the atmosphere. However, a conflicting disposal practice was indicated by Mr. Jimmy Kim (operator of the facility and son of owner/father Dae Kim), who believed that the waste stream had been formerly disposed to the facility's septic system or to the storm sewer located immediately behind the shopping center. The Bell facility operated over a period of 14.5 years from January 1988 through June 2002.

1.2.2.1 Previous Investigations

The Jones Road site has undergone numerous investigations from November 4, 1994 to the present by private environmental consulting companies and regulatory agencies and their subcontractors. A chronology of previous site investigations and significant events is summarized in **Table 1**, and additional detail is available in the RI report and on the Texas

Commission on Environmental Quality (TCEQ) web page, "Continuation of Jones Road History of Actions" located at:

http://www.tceq.state.tx.us/remediation/superfund/jonesroad/fullhistroy.html

1.2.2.2 Waste Type and Estimated Quantities of Source Materials

On September 12, 2002, the TCEQ prepared a *Compliance Evaluation Investigation* (CEI) report documenting several Notice of Violation (NOV) reports that had been issued to the Bell facility for mismanagement of waste manifests. The CEI report was included as Reference 21 of the *Hazard Ranking System Documentation* (TCEQ, April 2003).

The CEI discovered a liquid waste that was generated from the dry cleaning machine water separator that was not listed on the Bell facility notice of registration (NOR), and which should have been listed as F002 (spent PCE). At least three gallons of liquid per day was generated from the dry cleaner liquid separator. Based on a six-day work week and four weeks per month, the Bell facility should have generated approximately 579 pounds of liquid per month (6,948 pounds per year).

The CEI report also estimated that the facility generated an average of 95 pounds of PCE sludge (WS 0506609H) per month (1,140 pounds per year). However, the 1992 Annual Waste Summary (AWS) submitted by Bell indicated that 1.2 tons (2,400 pounds) of waste sludge was generated at the Bell facility.

Review of partial records provided by Bell indicated that Safety-Kleen Systems (SK) transported 5,115 pounds of waste PCE in 1999; 1,755 pounds in 2000; 1,157 pounds in 2001; and 787 pounds in 2002. Assuming that all of the sludge was disposed properly and that the liquids were not, as much as 6,948 pounds per year of liquid potentially could have been disposed improperly (behind the Bell facility or in the storm water drain or septic system).

The amount of potential PCE released can be compared to estimated amounts of PCE in the soil and groundwater. If the 6,948 pounds per year of liquid were 100% PCE, then there would have been 100,000 pounds of PCE released over 14.5 years. However, the liquid released was waste liquid and likely contained a much smaller fraction of PCE. The 6,948 pounds value was derived from a figure of 3 gallons of liquid per day with an assumed density of water, so the PCE fraction should be small enough to not change the overall density much, approximately 2% PCE for an upper limit. A reasonable lower limit would be the measured PCE concentration in waste liquid from April 2002 [94,900 micrograms per liter (µg/L)]. Other possibilities would be the highest measured groundwater concentration (167,000 µg/L) or the PCE solubility (200,000 µg/L). These fractions of PCE lead to estimated PCE release totals ranging from 9.5 to 3,245 pounds.

An estimate of PCE released can also be calculated from soil and groundwater test results. Estimated PCE in shallow groundwater (less than 50 feet bgs) was 461 pounds. Estimated PCE in deep groundwater (more than 50 feet bgs) was 81 pounds. Estimated PCE in soil was 633 pounds. The total estimated PCE was 1,176 pounds. This would be equivalent to a PCE fraction in waste liquids of 0.7%, somewhere between the PCE solubility and the highest PCE fraction evaluated (2%). Calculations for these mass estimates are included in **Appendix D**.

1.2.2.3 Waste Physical and Chemical Characteristics

The primary chemical of concern at this site is PCE. PCE is a manufactured chlorinated organic compound used as a solvent by automotive repair shops, paint shops, machine shops, and dry cleaning establishments. A single molecule of PCE consists of a double carbon bond surrounded by four chlorine atoms. PCE has a high vapor pressure (18.2 millimeters of mercury [mm Hg]), and it can easily evaporate into air or be partitioned from liquid into the vapor phase. PCE is a colorless nonflammable liquid at room temperature and has a density of 1.62 grams per cubic centimeter (g/cm^3) compared to water which is 1.00 g/cm^3 (*Groundwater Chemicals Desk Reference*, Montgomery and Welkom, 1989). Liquid PCE has a limited ability to mix with or dissolve in water and has a solubility of 200,000 µg/L. In other words, about 1.5 fluid ounces of PCE will dissolve in 100 gallons of water. If any additional PCE were added to this solution, it would exist as a separate liquid phase. Because PCE is denser than water and has a low solubility, PCE tends to sink through water and can exist in a saturated environment as a separate dense non-aqueous phase liquid (DNAPL). Therefore, when PCE is introduced into the subsurface, it sinks to the lowest point it can attain until reaching a low permeable barrier. At this point it spreads out under the influence of gravity (it can actually oppose groundwater flow) or can sink even further if fractures are present in the low permeable barrier. Unlike other hydrocarbons that are less dense than water and float near the surface of the water table, PCE can sink hundreds of feet through water, thus contaminating a much larger volume of groundwater as discussed in *Dense Chlorinated Solvents* (Pankow & Cherry, 1996).

1.2.3 Soil

1.2.3.1 Soil as a Potential Pathway

Soil in the source area has been determined to be a probable pathway for PCE migration to groundwater. Soil and groundwater samples, especially collected immediately behind the Bell facility, suggest that PCE has traveled through the soil and into the underlying groundwater-bearing units. Because the density of PCE is greater than that of water, it tends to move downward to the bottom of any sandy zone and pool on top of less permeable silt or clay layers. Density differences of ~1% influence fluid movement in the subsurface, and the density of PCE is 62% greater than that of water (1.62 compared to 1.00). The relatively high density of PCE means that it may penetrate the water table and flow vertically downward, directed by paths of least capillary resistance (possibly against the lateral direction of groundwater flow). PCE

penetrates clay by moving through fractures, and where clay layers are discontinuous, PCE will simply flow over the edges of discontinuous clay lenses and continue downward through more permeable material (Environment Agency R&D Publication 133, June 2003).

1.2.3.2 Nature and Extent of Soil Contamination

Figure 8 shows the Bell facility and surrounding properties with soil sample locations and source area monitor well locations. Several limited soil investigations were performed in the area until October 2003, when a thorough DPT investigation was conducted around the Bell facility, *Remedial Investigation – Geoprobe* (Shaw, April 28, 2004). Results of soil laboratory analysis indicted PCE, TCE, DCE, and VC impact to soil in nine of 21 DPT borings (GP-3, GP-4, GP-5, GP-6, GP-7, GP-8, GP-13, GP-16, and GP-20) with samples collected from four different sample zones (1 to 2 feet bgs; 16 to 19 feet bgs; 19 to 30 feet bgs; and 30 to 35 feet bgs). Review of the sample results concluded that PCE is the most prevalent contaminant within the upper 35 feet of site soils, with highest concentrations detected in soil borings GP-3 and GP-4 (located behind the Bell facility and representing the suspected primary discharge area). The highest PCE concentration in soil was 260 mg/kg, within the 16 to 17-foot depth sample collected from soil boring GP-4 (located behind the former dry cleaning facility).

Soil sampling was performed south of the septic system leach field and adjacent to the septic system drainage lines during the October 2003 DPT investigation. Some minor concentrations of PCE were detected in soil samples collected near the septic system leach field in soil borings GP-1 (0.009 mg/kg; estimated 18 to 19 feet bgs), GP-2 (0.003 mg/kg; estimated 1 to 2 feet bgs), GP-16 (0.029 mg/kg; 1 to 2 feet bgs), and GP-20 (0.018 mg/kg; 22 to 23 feet bgs). The highest concentration was detected in GP-20, which is located adjacent to the septic leach field. Two soil borings (GP-18 and GP-19) were installed directly south of the leach field, and PCE was not detected in soil samples taken from the borings. Results of the soil analyses indicate that the septic system may be a minor secondary source area of PCE compared to the major source area directly behind the Bell facility.

Another important soil investigation was performed in July 2006, titled *July 2006 Geoprobe Investigation* (Shaw, January 24, 2007). Nine DPT borings (GP-1A through GP-9A) were drilled to depths of approximately 50 feet bgs to support a bench-scale treatment study for application of in situ chemical oxidation and bioremediation remedies. Two of the highest PCE concentrations were detected in soil samples taken from soil in boring GP-3A within the 20 to 21-foot bgs interval (620 mg/kg) and within the 49 to 50-foot bgs interval (85 mg/kg). The third highest PCE concentration was detected in GP-2A within the 20 to 21-foot bgs interval (7.8 mg/kg). The sample locations for GP-3A and GP-2A were both behind the Bell facility (near the storm drain grate that drains (sub-grade) westward towards the open drainage ditch along Jones Road). Soil samples collected from the ditch in locations north and south of the Bell facility, GP-12 and GP-21, showed no detectable PCE. Review of the sample results concluded that

contaminants immediately behind the Bell facility are at least 50 feet bgs. No dense non-aqueous phase liquid (DNAPL) was observed during the investigation.

Figure 9 presents a map showing the distribution of PCE in soils around the former Bell facility. The map was prepared by plotting the highest PCE concentration detected in each sample location, regardless of depth, to a maximum depth of investigation of 50 feet bgs.

1.2.3.3 Soil Impact to Human or Environmental Receptors

The soils in the source area that are impacted with PCE near the ground surface (to a depth of approximately 20 feet bgs) are primarily covered with concrete associated with the building foundation (Cypress Shopping Center) and concrete parking lot/back alley. There is currently a low potential for human exposure to soil through dermal contact or ingestion. Exposure to burrowing animals is also unlikely considering the highly urbanized area and unlikely ecological habitat. The concern for PCE in soil at this site is migration of PCE from soil to groundwater.

1.2.4 Groundwater

1.2.4.1 Groundwater as a Potential Pathway

Groundwater is a known pathway for contaminant exposure, as PCE has been detected in the shallow WBU in and around the source area and also in numerous drinking water wells that obtain water from deeper drinking water aquifers at the Jones Road site. The groundwater pathway is completed when groundwater is pumped to the surface for consumption. As an interim measure the TCEQ installed granular activated carbon (GAC) filtration systems on wells where PCE concentrations were at or exceeded the maximum contaminant level (MCL). Counting only TCEQ maintained filtration systems, eight filtration systems were installed in 2002, and more filtration systems were installed in succeeding years leading to 35 filtration systems installed as of May 2008. The USEPA and TCEQ have completed installation of a water line at the Jones Road site to provide municipal water to the area (November 2008), which provided an alternate water supply to replace individual water wells used for water consumption. The TCEQ ceased maintaining the filtration systems with completion of the water line. With the completion of the water line connections for potable water delivery, the groundwater pathway is only complete for those households which chose not to connect to the water line and still use groundwater from a well in the plume area.

1.2.4.2 Nature and Extent of Groundwater Contamination

Groundwater contamination originates from soil contamination in the source area. Dissolution of PCE from impacted soils has created a groundwater plume that has migrated laterally and vertically away from the source area, and in a downgradient direction. In the shallow groundwater-bearing unit (less than 50 feet bgs) of the source area, the distribution of PCE in groundwater indicates that the groundwater flow direction is southwest (see **Figure 10**). However, the *Deep Monitor Well Groundwater Gauging and Rainfall Data* (Shaw, November

2007) report showed the flow direction within a deep aquifer (screened within depths from approximately 233 to 296 feet bgs) to be highly consistent to the southeast, with a groundwater gradient ranging from 0.00248 to 0.00267 ft/ft (see **Figure 7**).

Groundwater in the Source Area

A groundwater investigation was conducted in August and September 2003, titled *Remedial Investigation – CPT* (Shaw, April 2004). Thirty-six CPT borings (CPT-1 through CPT-7 and CPT-10 through CPT-38) were installed using CPT drilling methods, and three permanent monitor wells (MW-7, MW-8, and MW-9) were installed using hollow stem auger (HSA) drilling methods. The CPT sample points and monitor wells were installed for collection of groundwater samples; no soil samples were collected. PCE was detected in three CPT borings installed close to the Bell facility at depths of approximately 30 feet bgs. PCE concentrations in CPT-3, CPT-5, and CPT-6 were 3,810 µg/L, 62 µg/L, and 238 µg/L, respectively. One groundwater sample was taken from a depth of 51 feet bgs in downgradient soil boring (CPT-32), and PCE was detected at 2,480 µg/L. Monitor well MW-7 was subsequently installed near soil boring CPT-32, but the monitor well was screened to a depth of 35 feet to monitor the same groundwater-bearing unit as the other monitor wells in the area. The significance of the CPT investigation was that PCE had migrated from shallow source area soils to shallow groundwater in an apparent downgradient direction.

February 2008 mapping of PCE in the shallow source area monitor wells (less than 50 feet bgs) indicates that the PCE plume in the shallow zone has moved farther downgradient from the source area since it was investigated in 2003. The highest PCE concentrations are now detected in monitor well MW-6 near the southwest corner of the Cypress Shopping Center site. The concentration of PCE in monitor well MW-6 was 6,000 µg/L in August 2003, but increased to a concentration of 167,000 µg/L in February 2008. A similar increase in PCE concentrations has occurred in monitor well MW-1, which was installed immediately downgradient of the suspected source area. The concentration of PCE increased from 3,900 µg/L in August 2003 to 27,900 µg/L in February 2008. The increase in PCE in monitor well MW-1 could be an indication that PCE is still being released from soils in the suspected source area. **Figure 10** shows the distribution of PCE in shallow (less than 50 feet bgs) groundwater for the February 2008 sampling event.

Groundwater in Deeper Zones

The distribution of PCE in nearby commercial and residential water wells occurs primarily west, southwest, and southeast of the source area, but water wells located north and northwest of the source area are also impacted. Movement of the plume north and far west of the source area would not be expected under static groundwater flow conditions and in uniform/isotrophic geologic formations. However, groundwater flow conditions are likely not static; flow may be

influenced by seasonal pumping of numerous private and commercial water wells surrounding the source area. Historically, increased PCE concentrations have been observed during February and May sampling events, and may be related to surface drought conditions that promote increased water demand (pumping from water wells) to irrigate lawns in the area. PCE concentrations as high as 590 µg/L have been detected in the deep groundwater, but recent maximum concentrations have been less than 200 µg/L. Also, the subsurface geology is not uniform/isotrophic; the geology is comprised of complex fluvial deposits, such as paleo river channels and over-bank deposits that may provide lateral pathways to aquifers north and northwest of the source area. Estimates of the plume size based on surface distance measurements to impacted water wells, suggests that the width is approximately 2,000 feet, the length is approximately 3,000 feet, and the depth is approximately 300 feet. The text below provides a detailed discussion of contaminant distribution within the underlying WBUs with reference to figures. In addition, **Table 6** presents the quarterly PCE groundwater sampling results from May 2003 through February 2008.

At the Jones Road site, the complex subsurface geology precludes identification of distinct and continuous WBUs within the Chicot and Evangeline aquifers. As a proxy for distinct WBUs, the wells have been divided into various categories by screened intervals and depth to allow some analysis of travel paths for PCE contamination in the groundwater. The monitor wells and water wells have been divided into five groups, less than 200 feet bgs, 200 to 230 feet bgs, 231 to 260 feet bgs, 261 to 300 feet bgs, and 301 to 540 feet bgs. There are 49 wells (23 sampled) in the less than 200 feet group, 158 wells (65 sampled) in the 200 to 230 group, 94 wells (40 sampled) in the 231 to 260 group, 60 wells (19 sampled) in the 261 to 300 group, and 45 wells (8 sampled) in the 301 to 540 group. There are also 193 sampled wells for which the screened interval and total depth are unknown.

Wells Less Than 200 Feet BGS

For groundwater less than 200 feet bgs, the groundwater samples consist of many shallow samples at and near the Bell facility, including multiple samples from nine shallow source area (less than 50 feet bgs) monitor wells (MW-1 through MW-9) near the Bell facility, and multiple samples from 14 water wells to the south and mostly west of the Bell facility.

In groundwater from wells reported to be less than 200 feet bgs, PCE has been found above the MCL in wells at seven properties, FV11022, JR11600, TT11014, TT11106, TC11027, TC11107, and TC11115 (**Table 6**). It appears that PCE traveled vertically down and primarily southwest in the groundwater less than 200 feet bgs. The inferred groundwater flow direction is to the southwest. The PCE plume is bounded to the west by wells with PCE concentrations below the detection limit, but not in other directions. **Figure 11** shows the inferred groundwater plume of PCE greater than the MCL in groundwater less than 200 feet bgs for November 2007.

Wells 200 to 230 Feet BGS

For groundwater in wells reported to be between 200 and 230 feet bgs, the groundwater samples consist of multiple samples from 65 water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 200 to 230 feet bgs, PCE has been found above the MCL at nine locations, FV11102, JR11427, JR11527, JR11600, TC11126, TH11723, TO10835, TT11011, and TT11107. FV11022 was only sampled once, and TH11723 only had PCE exceeding the MCL once. The others consistently had PCE concentrations exceeding the MCL (**Table 6**). It appears that PCE continued downward and primarily southeast in the groundwater 200 to 230 feet bgs. The inferred groundwater flow direction is to the southeast. The 200-230 PCE plume is bounded from the south around to the northwest, and on part of the east side, but not in other directions. **Figure 12** shows the inferred groundwater plume of PCE greater than the MCL in groundwater from 200 to 230 feet bgs for November 2007.

Wells 231 to 260 Feet BGS

For groundwater in wells reported to be between 231 and 260 feet bgs, the groundwater samples consist of multiple samples from 2 monitor wells and 38 water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 231 to 260 feet bgs, PCE has been found above the MCL at seven locations, FV11014, FV11130, TC11019, TO10903, TO11024, TT11123 and TT11127. Sampling at TO11024 ended in May 2006. The others consistently had PCE concentrations exceeding the MCL (**Table 6**). It appears that PCE continued downward and slightly northwest in the groundwater 231 to 260 feet bgs. The inferred groundwater flow direction is to the southeast. The 231-260 PCE plume is bounded from the west around to the north, and partially to the southeast, but not in other directions. **Figure 13** shows the inferred groundwater plume of PCE greater than the MCL in groundwater from 231 to 260 feet bgs for November 2007.

Wells 261 to 300 Feet BGS

For groundwater in wells reported to be between 261 and 300 feet bgs, the groundwater samples consist of multiple samples from seven monitor wells and 12 water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 261 to 300 feet bgs, PCE has not been found above the MCL (**Table 6**). There have been some scattered detections at concentrations below the MCL, but nothing consistent. It appears that PCE continued downward and slightly northwest in the groundwater 261 to 300 feet bgs, but PCE at concentrations above the MCL have not reached lower WBUs. The inferred groundwater flow direction is to the southeast, which has been well documented by groundwater elevations in the monitor wells. Seven monitor wells surround the PCE plume, and PCE has not been detected in any of the monitor wells screened to total depths between 258 and 297 feet bgs. Although VC was detected in several monitor wells in November 2007, samples from February 2008 did not detect VC. This brief appearance of VC, a product of PCE degradation, may be an indication that natural

degradation processes are active. **Figure 14** shows the inferred groundwater plume for properties with wells screened in groundwater from 261 to 300 feet bgs for November 2007.

Wells 301 to 535 Feet BGS

At the Jones Road site, PCE, TCE, DCE, and VC were not detected above MCLs in water samples collected from water wells drilled deeper than 300 feet bgs.

For groundwater between 301 and 535 feet bgs, the groundwater samples consist of multiple samples from one monitor well and seven water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 301 to 535 feet bgs, PCE has not been detected above the MCL (**Table 6**). There has been only one detection of PCE (0.23 µg/L at WE10814 in February 2006), but it was less than the MCL. It appears that PCE continued downward and slightly north in the groundwater 301 to 535 feet bgs, but consistently detectable PCE has not reached this depth. The inferred groundwater flow direction is to the southeast. The water well at 11115 Tall Timbers Drive is located near the center of the dissolved-phase PCE plume within overlying sand units, and the water well at 11414 Jones Road lies under the southeast arm of the plume. The other deep wells are located beyond the known area of the plume. **Figure 15** shows the inferred groundwater plume for properties with wells screened in groundwater from 301 to 535 feet bgs for November 2007.

Wells of Unknown Depth

In the wells of unknown depth, groundwater samples were collected from 148 water wells to the north, west, south, and east of the Bell facility. Of the 148 water wells of unknown depth, 103 had PCE concentrations below the detection limits, but were not used to delineate the horizontal extent of PCE at any particular depth, 27 had detectable PCE concentrations less than the MCL, and 18 had detectable PCE concentrations exceeding the MCL (**Table 6**). The 18 wells of unknown depth with PCE concentrations exceeding the MCL are located within the plume boundaries.

1.2.4.3 Groundwater Impact to Human or Environmental Receptors

The groundwater exposure pathway is complete at the Jones Road site. However, installation of GAC filtration systems, along with quarterly groundwater monitoring, was implemented as an interim precaution to prevent exposure to humans. In addition, a government funded water line has been constructed to provide a reliable source of safe drinking water to the community from the White Oak Bend MUD. Connection to the water line was voluntary. Household participation has been approximately 51% for water line connections, while 49% remain on wells. Groundwater is not known to impact any ecological receptors.

1.2.5 Surface Water and Sediments

Sediment sampling was not conducted at the Jones Road site to assess potential impact of sediments by PCE. However, three soil borings were installed within the northerly trending drainage ditch between Cypress Shopping Center and Jones Road during a soil investigation in October 2003; see **Figure 8** and Section 2.1.2.8 of the *Remedial Investigation – Geoprobe* (Shaw, April 28, 2004). DPT soil boring GP-13 was installed at the intersection of the drainage ditch and the Bell facility storm sewer outfall. Soil boring GP-21 was installed in the drainage ditch approximately 70 feet north of soil boring GP-13, and soil boring GP-12 was installed within the drainage ditch approximately 90 feet south of GP-13.

Estimated low concentrations of PCE (0.002 mg/kg) and TCE (0.004 mg/kg) in the near surface soil sample (1 to 2 feet bgs sample interval) of soil boring GP-13, along with no PCE or TCE concentrations above the detection limits in near surface soil samples collected from soil borings GP-12 and GP-21 may indicate that the overlying sediment in the drainage ditch likely contains only minor PCE or TCE concentrations, since the contaminants would be expected to leach downward from sediments into the shallow surface soils. It appears that a small release may have occurred along the drainage ditch, but significant accumulation of contamination is not apparent. For the same reason, transportation of contaminants in waters of the ditches was likely minimal. No known surface waters have been impacted by PCE released from the source area.

1.2.5.1 Pathway and Location(s), of Contaminant Entry to Surface Waters

No pathways of contamination entry to surface waters are known at this time.

1.2.5.2 Nature and Extent of Sediment Contamination

No sediment contamination is known at this time; only near surface soil samples were collected from the roadside ditch as explained above.

1.2.5.3 Contaminated Sediment Impact to Human or Environmental Receptors

No sediment contamination is known at this time.

1.2.6 Air

1.2.6.1 Air as a Potential Pathway

No studies have been performed to determine if outside air poses a threat to human health or the environment. However, a vapor intrusion study was performed at the former Bell facility, *Vapor Intrusion Study* (Shaw, May 6, 2008) to determine if completed pathway(s) exist for intrusion of vapors to workers in the Cypress Shopping Center (from the Bell facility), and if indoor vapors could pose an unacceptable risk of chronic health effects due to long term exposure. **Figure 8** shows the locations of the air samples collected.

1.2.6.2 Nature and Extent of Indoor Air Contamination

During the *Vapor Intrusion Study* two indoor ambient air samples and two sub-slab air samples were collected inside the former Bell facility, for analysis of volatile organic compounds (VOCs) using USEPA Method TO-15. Results of laboratory analysis were compared to the Tier II Table from the OSWER *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (USEPA, 2002). PCE and TCE exhibited higher concentrations than the OSWER Tier II target concentrations for the two ambient air samples. In one ambient air sample, the PCE and TCE concentrations were 14 micrograms per cubic meter ($\mu g/m^3$) and 1.8 ($\mu g/m^3$), respectively. For the other ambient air sample, the PCE and TCE concentrations were 9.5 ($\mu g/m^3$) and 1.7 ($\mu g/m^3$), respectively. Fourteen other chemicals were detected but did not exceed the OSWER Tier II target concentrations, and were suspected to be related to household compounds (and other chemicals stored on-site) that would be expected to be found at low concentrations in ambient indoor air.

Eight chemicals were detected in the sub-slab samples. PCE and TCE concentrations were 47,300 ($\mu g/m^3$) and 9,080 ($\mu g/m^3$) in one sub-slab sample, and 59,700 ($\mu g/m^3$) and 1,930 ($\mu g/m^3$) in another sub-slab sample, respectively. The sub-slab samples were evaluated by estimating attenuation factors relative to soil or groundwater concentrations to indoor air concentrations.

1.2.6.3 Contaminated Air Impact to Human or Environmental Receptors

For indoor air, the *Vapor Intrusion Study* concluded that a complete pathway for vapor intrusion exists, but very little vapor is migrating from the sub-slab soil into indoor air (the slab is an effective barrier to limit vapor intrusion). The report also concluded that VOCs measured in indoor air did not pose an unacceptable health risk to workers. No outdoor air investigations were performed to evaluate impact to human health or environmental receptors.

1.2.7 Exposure Pathways

The TCEQ Memo dated October 21, 2003, *Determining Which Releases are Subject to TRRP* describes the process for evaluating exposure pathways. Soil is evaluated separately as surface soil and subsurface soil. Surface soil is evaluated against the combined pathway protective concentration limits (PCLs) and the ingestion pathway PCLs. Subsurface soil is evaluated against the ingestion pathway PCLs and the vapor pathway PCLs. Groundwater is evaluated against the ingestion pathway PCLs and the vapor pathway PCLs.

At the Jones Road site, the soil pathways were evaluated and determined to be incomplete. The development of the land over the contaminant source area includes buildings, parking lots, and roadways, all of which combine to limit direct contact with the soil and discourage prolonged human presence in the area.

The vapor pathways were evaluated in the *Vapor Intrusion Study* (Shaw, May 2008). The conclusion of that study was that the presence of buildings and pavement in the source area limits exposure along the vapor pathway from either soil or groundwater.

The groundwater pathway was evaluated and found to be complete. Chemicals are present in groundwater at levels exceeding the groundwater ingestion pathway PCLs. Public and private water wells tap into groundwater and provide it for domestic and commercial use, completing the groundwater ingestion pathway.

1.2.7.1 TRRP Groundwater Classification

Groundwater resources below a depth of approximately 60 feet are used or are potentially used for human consumption. The regulatory citation for groundwater classification is 30 Texas Administrative Code (TAC) §350.52. The *TCEQ Regulatory Guidance on Groundwater Classification* (RG-366/TRRP-8) (TCEQ, March 2003), outlines the process of groundwater classification.

Under the Texas Risk Reduction Program (TRRP) rule, groundwater is classified as Class 1, Class 2, or Class 3, with Class 1 groundwater being the most desirable and best groundwater for human consumption, and Class 3 groundwater being the least desirable and likely not useable for human consumption. The groundwater tapped by private and public water supply wells at the Jones Road site is classified as Class 1 groundwater. The criteria for a Class 1 groundwater resource are:

- The affected WBU is within 0.5 miles of a PWS well and COCs could migrate to the well production zone; or
- The affected WBU is the only reliable source of water in area, with a depth < 800 ft below grade, total dissolved solids concentration less than 1,000,000 µg/L, and sustainable well yield greater than 5,000 gallons per day.

Because PCE is present at levels above the MCL in the PWS well at the former Finch's Gymnastics at the Jones Road site, the groundwater must be Class 1 groundwater according to the first criterion. Additional PWS wells in the area are found at 11600 Jones Road (the Cypress Shopping Center), 11035 Jones Road (Schlotzsky's Deli), and 11338 Tower Oaks Boulevard (the Little School House).

The criteria for Class 2 groundwater are:

- The affected WBU is a production zone for an existing water supply well (other than PWS well) within 0.5 miles which is used for human consumption, agriculture, or other purpose which could result in human or ecological exposure.

If there were no PWS wells at the Jones Road site, the groundwater could be a Class 2 groundwater. Because PWS wells are present, the groundwater is Class 1.

1.2.7.2 Source Area TRRP Groundwater Classification

Based on the *General Groundwater (Inorganic) Quality Characterization and Comparison* report (Shaw 2004), total dissolved solids (TDS) values for monitor wells MW-7, MW-8, and MW-9 (shallow WBU monitor wells surrounding the source area) ranged from 408 to 508 mg/L, which are concentrations below the Class 3 classification criteria. Because shallow wells in the surrounding areas are in hydraulic communication with much deeper WBUs, and the same contaminants are present in both the shallow source area WBU and the deep drinking water aquifers, the groundwater intercepted by the shallow source area monitor wells would most likely be a Class 1 groundwater resource (by regulatory definition; impact to a nearby public water supply well).

In accordance with 30 TAC §350.52(1)(A), any groundwater-bearing unit within 1/2 mile of an existing well used to supply drinking water to a public water system which can contribute COCs to the groundwater production zone of such public water supply well based on the chemical properties of the COCs, the hydrogeology, and the construction of the well is considered Class 1 groundwater. Case in point: MW-1 has had historic PCE concentrations ranging from 3,900 to 29,000 µg/L, and the PWS well at the former Finch gymnastics (about 1500 feet SE of MW-1) has had historic PCE concentrations ranging from 7.9 to 87.9 µg/L. Also, the PWS well at the strip center where the former Bell Cleaners was located has had historic PCE concentrations ranging from 0.8 to 7.1 µ/L (PCE concentration ranges reported for both PWS wells from 2003 to 2008).

The classification was not determined by well yield. However, well yield is recognized as a data gap since the information is necessary for implementation of a remedy alternative. Groundwater intercepted by shallow monitor wells in the source area (less than 50 feet bgs) has not been tested for well yield. One of the shallow source area monitor wells (MW-6), is intermittently dry, and the hydraulic conductivity measured in soil boring GP-9A was lower than the regulatory threshold value required for a saturated formation to be classified as a WBU (30 TAC 350.52 or RG-366/TRRP-8, March 2003).

1.2.8 Contaminant Fate and Transport

PCE within soils below the former Bell facility provide a continuous source of contamination to shallow WBUs. The fluvial nature of subsurface strata may provide preferential pathways for contaminant transportation from the shallow WBUs to the deeper WBUs through coalescing paleo river channels or overbank deposits. Groundwater withdrawals through water wells may also influence the direction of plume movement toward the neighborhood, especially during

seasons of high water demand. Migration to deeper WBUs in the Chicot Aquifer and upper Evangeline Aquifer may be limited by aquitards that separate the sand units.

A plume migration rate of 150 feet per year (ft/yr) was suggested at the April 20, 2004 public meeting. That estimate was based on the information available at the time. Since then, the PCE plume has expanded slightly to the south, west, and north, but at nowhere near the April 20, 2004 estimate. A revised estimate of plume migration rate based on information available through May 2008 has been calculated to be 90 ft/yr, based on a plume length of 1800 feet (from the source area) divided by 20 years (approximate time of PCE release) (**Figure 16**).

1.2.9 Baseline Risk Assessment

Previous investigations have shown that potential use of groundwater could contribute to human health risk. The physical characteristics of the chlorinated hydrocarbons being investigated at the site enable them to be classified as VOCs, as they will evaporate or volatilize when in contact with air. The risk assessment focused on PCE and its major degradation products, including TCE, DCE (cis-1,2-DCE and trans-1,2-DCE), and VC at concentrations that have been measured in groundwater and indoor air media. PCE and daughter product concentrations in groundwater exceed federal MCLs and pose a risk to human health if consumed. The risks are explained in detail in the *Baseline Risk Assessment* (Shaw, August 2008), and are also summarized in Section 6.0 of the *Final Remedial Investigation Report* (Shaw, February 2009).

1.2.9.1 Groundwater

To evaluate exposure over a range of possible conditions that may exist at the site, two hypothetical degrees of exposure are normally considered in a risk assessment: reasonable maximum exposure (RME) and central tendency exposure (CTE). While the RME does not represent the maximum exposure expected at a site, it does represent the highest exposure that is reasonably expected to occur. The CTE is intended to represent more typical (i.e., central tendency or average) exposure conditions. Because all constituents of potential concern (COPCs) identified in groundwater at the site have MCLs, they were designated as COCs and exposures were not evaluated in the BLRA.

At chlorinated solvent sites, PCE and its degradation products are commonly identified as COCs, and their MCLs are selected as cleanup levels in the Record of Decision. The basis for this approach is OSWER Directive 9355.0-30, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (USEPA, 1991a), which states that chemical-specific standards that define acceptable risk levels (e.g., MCLs) may be used to determine whether an exposure is associated with an unacceptable risk to human health or the environment and whether remedial action is warranted.

1.2.9.2 Indoor Air

Because only two indoor air samples were analyzed, no statistical analysis of the vapor concentration values was made; the exposure assessment was made using the maximum concentration of each COPC. The two air samples were collected within the Center Room of the Former Bell dry cleaner facility. Concentrations of vapor measured indoors at the site were compared to Draft USEPA (2002) air screening levels and Draft TCEQ screening levels based on residential or commercial risk-based exposure levels ($^{Air}RBEL_{Inh}$) based on the TRRP rule [30 TAC §350.74]. Site-related contaminants (PCE, TCE, and cis-l,2-DCE) were detected, with PCE and TCE measured above conservative Draft USEPA screening levels in both indoor air samples. None of the compounds in indoor air exceed conservative Draft TCEQ screening levels based on residential or commercial $^{Air}RBEL_{Inh}$ levels from the TRRP rule.

Estimated cancer risk for the hypothetical resident at the Center Room location ranged from 3.6E-05 to 7.2E-05 in the case of the adult resident. For the child resident, the estimated inhalation risk is 1.7E-05. The estimated cancer risk for a hypothetical indoor worker at the Center Room location was 1.4E-05. All cancer risk estimates are within the acceptable range of 1E-06 to 1E-04 established by USEPA (1989) guidance.

The estimated non-cancer hazard for the hypothetical resident at the Center Room location was 9.1E-02, well below the acceptable hazard index (HI) of 1.

For the child resident, inhalation hazard was estimated as 2.0E-01, which is below the acceptable HI value established by USEPA (1989) guidance. The estimated non-cancer hazard for the hypothetical indoor worker at the Center Room location was 3.9E-02.

1.2.9.3 Environmental Evaluation

Potential ecological risks for the site were evaluated according to the Tier 1 Exclusion Criteria Checklist specified in Title 30 of the Texas Administrative Code [30 TAC §350.77(b)]. Based on this checklist, no action is required at the Jones Road site to protect ecological receptors. The completed Tier 1 Exclusion Criteria Checklist is shown in Appendix D of the RI.

2.0 Identification and Screening of Technologies

2.1 Introduction

This section provides a discussion of the existing RAOs for the Jones Road site, a discussion of the development of RAOs and PRGs for the Jones Road site, and an evaluation of ARARs related to the Jones Road site.

2.2 Remedial Action Objectives

RAOs are developed to specify the constituents of concern (COCs), exposure route(s) and receptor(s), and an acceptable contaminant level or range of levels for each exposure route, i.e., PRGs (USEPA, 1988). RAOs are selected first, and then remedial approaches are evaluated to meet the RAOs. In order to consider a remedial alternative, it must be protective of human health and the environment, and comply with all ARARs. As a function of establishing RAOs and PRGs, ARARs must be reviewed to identify the promulgated federal, state, and local standards that will or may affect the selection of response actions and future land use of the Jones Road site. The Jones Road site is comprised of two major areas of concern: the source area near the former Bell Dry Cleaner store (herein referred to as the source area), where shallow soil and groundwater were impacted; and the groundwater plume underlying adjacent neighborhoods, generally impacting deeper, potable water supplies (herein referred to as the deep groundwater plume). The exposure route found to be most significant for the Jones Road site was groundwater. Soil in the source area will be addressed as a source of contaminants that may continue to leach and impact shallow groundwater in the source area and the deeper groundwater plume. Risks associated with indoor air concentrations were evaluated in the RI and found to be within acceptable levels.

The following RAOs were established for soil and groundwater:

Soil

- Remove, isolate, or minimize migration of contaminants currently residing in site soils within the source area.

Source Area Groundwater

- Remove and/or treat groundwater containing concentrations exceeding MCLs established under the Safe Drinking Water Act (SDWA); restore all impacted WBUs for use by the local community.

- Prevent or minimize source area migration/expansion and contribution to the existing dissolved phase plume.

Deep Groundwater Plume

- Remove and/or treat groundwater containing concentrations exceeding MCLs established under the SDWA; restore all impacted WBUs for use by the local community.
- Prevent current and future use of the groundwater impacted by past site operations with ground water contaminants in excess of the MCLs.
- Prevent or minimize the potential that groundwater contaminants from the existing source areas and deep groundwater plume could migrate laterally or vertically to wells in the surrounding area serving private properties or MUD districts.

2.2.1 Contaminants of Interest

The contaminants of interest at the Jones Road site are PCE and its daughter products, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC. These contaminants are of interest because they appear or have appeared in the groundwater at concentrations higher than the MCLs. These contaminants of interest are typical for sites associated with dry cleaning operations.

The same contaminants are of interest in the soil, as these contaminants in soil may leach into groundwater at concentrations higher than the MCLs.

2.2.2 Allowable Exposure Based on Risk Assessment

Previous investigations have shown that potential ingestion of groundwater could contribute to human health risk. The physical characteristics of the chlorinated hydrocarbons being investigated at the Jones Road site enable them to be classified as volatile organic chemicals (VOCs), as they will evaporate, or volatilize, when in contact with air. The risk assessment focused on PCE and its major degradation products, including TCE, DCE (cis-1,2-DCE and trans-1,2-DCE), and VC at concentrations that have been measured in groundwater and indoor air media.

Results of a Baseline Risk Assessment (Shaw, 2008), concluded that groundwater posed unacceptable risks based on exceedances of MCLs, but indoor air did not pose unacceptable risks. Also, ecological risks were evaluated and it was concluded that no action is required at the Jones Road site to protect ecological receptors.

2.2.3 ARARs

As stated in 40 CFR Section 300.415(i), the chosen response action must attain, to the extent practicable, ARARs under federal, state, or local environmental laws. RAOs and PRGs established for a site must consider ARARs. Under CERCLA, a requirement may be either "applicable" or "relevant and appropriate" to a specific response action, but not both. The NCP (40 CFR Section 300.5) defines "applicable" and "relevant and appropriate" requirements as follows:

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

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal, state, and local environmental laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site.

Typically, ARARs are compiled in three categories: chemical-specific, action-specific, and location-specific. The primary factors that influenced selection of the ARARs for the Jones Road site were the elevated contaminant levels found in potable groundwater and activities that could be a part of the potential response actions associated with presumptive remedies as summarized in this report.

In addition to ARARs, 40 CFR 300.400(g)(3) states that federal, state, and local non-promulgated advisories or guidance may be identified as to-be-considered (TBC) guidance for contaminants, conditions, and/or actions at the site. TBCs include non-promulgated criteria, advisories, guidance, and proposed standards. TBCs are not ARARs because they are neither promulgated nor enforceable. TBCs may be used to interpret ARARs and to determine preliminary cleanup levels when ARARs do not exist for particular contaminants or are not sufficiently protective to develop cleanup levels. TBCs, such as guidance or policy documents, developed to implement regulations may be considered and used where necessary to ensure protectiveness.

Remedial actions must be protective of human health and the environment; Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent federal, state, and local environmental requirements, as well as to adequately protect human health and the environment. The definitions of ARARs used in this document were derived from USEPA's OSWER Directive No. 9234.1-01 CERCLA Compliance with Other Laws Manual (USEPA, 1988b).

2.2.3.1 Federal ARARs

Table 2 presents federal ARARs and TBCs that may apply at the Jones Road site. The primary chemical-specific ARARs are the Safe Drinking Water Act (SDWA) because the deep groundwater has been used for drinking water, and the MCLs because they are allowable levels

of contaminants for drinking water. The applicable action-specific ARARs change depending on the alternative in question, but Occupational Safety and Health Administration (OSHA) requirements would apply to all alternatives. The applicable location-specific ARARs primarily concern CERCLA, which exempts Superfund sites from permitting requirements, but requires that the substantive requirements of regulations be met.

2.2.3.2 State ARARs

Table 2 presents State of Texas ARARs and guidance TBC that may apply at the Jones Road site. The primary applicable chemical-specific ARARs are the Texas Surface Water Quality Standards because they would apply to any surface water discharges. The primary applicable action-specific ARARs are those governing installation, use, and abandonment of wells. The primary applicable location-specific ARAR is the Texas Department of Licensing and Regulation, which is the agency concerned with the existing and future institutional controls restricting groundwater use at the Jones Road site.

2.2.3.3 Local ARARs

Table 2 presents local ARARs and guidance TBC that may apply at the Jones Road site. The Harris County rule which prohibits drilling of water wells in a contaminated plume designated by USEPA and/or TCEQ is a local ARAR. The primary applicable TBCs are those associated with the Harris-Galveston Subsidence District which apply to groundwater withdrawal. The District requires registration of domestic wells but does not permit domestic wells. These are not ARARs because the District specifically exempts monitor wells and extraction/injection wells for remedial actions. The City of Houston POTW pretreatment requirements would apply to any remedial action that released water to a POTW.

2.2.4 Development of Remediation Goals

Remediation goals for soil are based on the expectation that contaminants left in place would not leach into the groundwater at concentrations above the MCLs. The values listed in the table below come from the Tier 1 residential protective concentration levels (PCLs) for soil protective of groundwater ($^{GW}Soil_{Ing}$) (TRRP, 30 TAC §350.72(b), Table 1 PCLs).

Remediation Goals for Soil

Chemical	Abbreviation	PRG (mg/kg)
Tetrachloroethylene	PCE	0.05
Trichloroethylene	TCE	0.034
cis-1,2-Dichloroethylene	cis-1,2-DCE	0.25
trans-1,2-Dichloroethylene	trans-1,2-DCE	0.49
Vinyl Chloride	VC	0.022

PCE and daughter product concentrations in groundwater that exceed federal MCLs pose a risk to human health if consumed. The MCL values constitute the allowable exposure level for these contaminants in groundwater. Remediation goals for groundwater are set equal to the MCLs.

Remediation Goals for Groundwater

Chemical	Abbreviation	PRG (µg/L)
Tetrachloroethylene	PCE	5
Trichloroethylene	TCE	5
cis-1,2-Dichloroethylene	cis-1,2-DCE	70
trans-1,2-Dichloroethylene	trans-1,2-DCE	100
Vinyl Chloride	VC	2

2.3 General Response Actions

The media of interest at the Jones Road site are soil and groundwater. In the source area, COCs are concentrated in shallow soils and groundwater. The COCs have also migrated to the deeper drinking water aquifers below nearby residential areas. For logistical purposes of implementing remedies to address GRAs for deeper drinking water aquifers, the associated groundwater plume should be considered relative to its location east or west of Jones Road. Jones Road is a major road that may prevent implementation of remedies using a single system or process. For instance, if groundwater pumping is an engineering control used to prevent migration of the PCE plume, then individual pumping/treating facilities may be required on both sides of Jones Road.

The primary COC by mass is PCE. The estimated mass of PCE in soil is approximately 633 pounds, accounting for 54% of estimated mass. The estimated mass of PCE in groundwater is 461 pounds in the shallow groundwater (39%) and 81 pounds in the deep groundwater (7%). From these estimates, it appears most of the PCE (93%) remains in the shallow soil or groundwater of the source area. However, the exposure to PCE comes through private water wells extracting water from the deep drinking water aquifers with only 7% of the estimated PCE, as calculated in **Appendix D.**

2.3.1 Soil – Source Area

The assumed extent of soil exceeding the PRGs for PCE is presented in **Figure 9**, which illustrates the PCE-in-soil extent at the source area. The extent of soil contamination exceeding PRGs for soil has been assumed to be the area within the 0.05 mg/kg concentration line on **Figure 9**. The impacted soil is regarded as a principal threat waste because of its potential to impact additional groundwater. Although high concentrations of PCE have been detected in soil, no dense non-aqueous phase liquid (DNAPL) was observed during site investigations documented in the *Remedial Investigation* (Shaw, 2009). The lack of observed DNAPL in soils and/or groundwater is a common occurrence to dry cleaner sites per e-mail correspondence

between the TCEQ Dry Cleaner Remediation Program and Marilyn Long of the TCEQ Superfund Section (TCEQ, 2009).

For cost estimation purposes, the area of soil exceeding PRGs at the source area is assumed to be approximately 26,000 square feet (ft^2), and extends to a depth of 20 feet bgs. These assumed dimensions give a volume of approximately 33,000 cubic yards when coupled with excavation side slopes of 2 to 1.

2.3.2 Groundwater – Source Area

In the shallow groundwater (less than 50 feet bgs) in the source area, the distribution of PCE in the groundwater is as shown on **Figure 10**. The areal extent of groundwater contamination exceeding PRGs for groundwater at the source area has been assumed to be the area within the 1,000 µg/L concentration line on **Figure 10**. Permeable strata within the interbedded zone of the source area shallow soils have been estimated to be approximately 10 feet thick based upon review of lithologic logs prepared for monitor wells MW-1 through MW-6, and from cone penetration testing (CPT) logs shown by Cross Section A-A' in **Figure 4**. The type log presented in **Figure 4A** does not clearly show a WBU within the shallow (less than 50 feet bgs) strata, possibly because the type log is not located in the source area, and/or the shallow WBUs are discontinuous in the type log area.

For cost estimation purposes, the volume of groundwater exceeding PRGs at the source area is assumed to be an approximately 60,000 ft^2, with an average thickness of 10 feet, and an assumed porosity of 0.25. These assumptions give a source area contaminated groundwater volume of 1.1 million gallons.

2.3.3 Groundwater – Areas West of Jones Road

In the area west of Jones Road, PCE in groundwater exceeds the PRG to different extents at different depth ranges. In groundwater less than 200 feet bgs, PCE has migrated the farthest south, to Neeshaw Drive (**Figure 11**). In groundwater between 200 and 230 feet bgs, PCE has migrated the farthest west, to Timber Hollow Drive (**Figure 12**). In groundwater between 231 and 260 feet bgs, PCE has migrated the farthest north, to Woodedge Drive (**Figure 13**). PCE contamination in groundwater has not been found deeper than 260 feet bgs (**Figure 14** and **Figure 15**).

The type log presented in **Figure 4A** shows an example of the general superposition of drinking water aquifers in the Jones Road area. As discussed earlier in this document and also in the *Remedial Investigation* (Shaw, 2009), the aquifers are highly variable in thickness and interconnectivity, as shown by other water wells installed in the area (see cross sections B-B' and C-C' in **Figures 5 and 6**, respectively). The deep drinking water aquifers impacted by dissolved-phase PCE extend from 50 feet below ground surface (shallow boundary definition) to

approximately 260 feet below ground surface, as shown in **Figures 11, 12, and 13**. The overlapping extent of deep groundwater plumes is presented on **Figure 16**, which has an aerial extent of approximately 2,076,096 square feet west of Jones Road. The average net sand thickness of PCE impacted aquifers, as calculated by tallying the sand units from the logs presented in **Figures 4A, 5 and 6** from 50 to 260 feet bgs is approximately 127 feet, with thicknesses that range from approximately 60 feet in water well G1010016A, to approximately 162 feet in monitor well MW-17. Using a porosity estimate of 25%, the estimated volume of PCE impacted groundwater in the deep drinking water aquifers within the 50 to 260-foot interval west of Jones Road is 493 million gallons. This should be regarded as a high end estimate because the groundwater plume area at individual depth intervals is smaller than the overlapping plume extent.

2.3.4 Groundwater – Areas East of Jones Road

In the area east of Jones Road, PCE in groundwater exceeds the PRG farther to the south with greater depth. In groundwater less than 200 feet bgs, PCE has migrated to Tower Oaks Boulevard (**Figure 11**). In groundwater between 200 and 230 feet bgs, PCE has migrated to the south side of Tower Oaks Boulevard (**Figure 12**). In groundwater between 231 and 260 feet bgs, PCE has migrated to the property across from Neeshaw Drive (**Figure 13**). PCE contamination in groundwater has not been found deeper than 260 feet bgs (**Figure 14** and **Figure 15**). Groundwater does not appear to be migrating significantly toward the east, and is not migrating to the north on the east side of Jones Road.

The overlapping extent of deep groundwater plumes presented on **Figure 16** has an aerial extent of approximately 1,308,183 square feet east of Jones Road. The average net sand thickness of PCE impacted aquifers is approximately 127 feet as noted above. Using a porosity estimate of 25%, the estimated volume of PCE impacted groundwater in the deep drinking water aquifers within the 50 to 260-foot interval east of Jones Road is 311 million gallons. This should be regarded as a high end estimate because the groundwater plume area at individual depth intervals is smaller than the overlapping plume extent.

2.4 Identification and Screening of Technology Types and Process Options

The use of the presumptive remedy approach for sites with contaminated groundwater outlined in the USEPA guidance document *Presumptive Response Strategy and Ex Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance* (USEPA, 1996) has been deemed appropriate for consideration at the Jones Road Site. This section describes the presumptive remedy technology options available under the guidance and reviews their applicability in light of the specific conditions documented at the Jones Road site and the RAOs/PRGs established for the Jones Road site.

2.4.1 Identification and Screening of Soil Technologies

Current USEPA guidance for treatment of VOCs in soils (USEPA, 1993) includes the following presumptive remedial technologies:

- Soil Vapor Extraction (SVE)
- Ex Situ Thermal Desorption
- Ex Situ Thermal Incineration

All the presumptive remedies presented above are well understood methods that have been used for many years in the treatment of VOCs in soil (USEPA, 1993). Excavation is a removal action, but not a remedial technology. Excavation was not a presumptive remedial technology identified in the 1993 USEPA document, but may be considered as a fourth remedial option for shallow soils at the Jones Road site.

2.4.2 Identification and Screening of In Situ Groundwater Technologies

Technologies for in situ groundwater treatment (possibly using injection wells) will be considered for the Jones Road site. Some types of in situ treatment bypass the need for pumping, piping, and treatment plant design while eliminating potential contaminant exposure. In Situ treatment measures evaluated for the Jones Road site are bioremediation (ITRC, 2002) and chemical oxidation (ITRC, 2005), and are considered for both the source area groundwater and the deep groundwater plume. For shallow source area groundwater, it is understood that chemical oxidation would have a dual purpose of treating both groundwater and soil.

In addition to these technologies, the USEPA guidance document also states that natural attenuation may be an appropriate remedial approach for portions of the contaminant plume when combined with other remedial measures needed to control sources and/or remediate "hot spots" (USEPA, 1996). The NCP defines natural attenuation as "biodegradation, dispersion, dilution, and adsorption" of contaminants in groundwater (Federal Register, 1990, Preamble at 8734). The NCP also states that natural attenuation may be a useful remedial approach if site-specific data indicate that these processes will effectively reduce contaminants in the groundwater to concentrations protective of human health and the environment in a timeframe comparable to that which could be achieved through active restoration. Containment is also considered for source area groundwater and the deep groundwater plume. Physical containment may be possible for the source area groundwater, while hydraulic containment/pump and treat may be necessary for the deep groundwater plume. A combination of any/all technologies discussed above is implied.

2.4.3 Identification and Screening of Ex Situ Groundwater Technologies

The following is a list of the presumptive remedy treatment options defined by the USEPA for sites contaminated with organic chemicals (USEPA, 1996). These technologies would apply to the source area groundwater and the deep groundwater plume. Presumptive technologies for treatment of extracted groundwater with dissolved organic chemicals are as follows:

- Air stripping
- Granular activated carbon (GAC)
- Chemical/ultraviolet (UV) oxidation
- Aerobic biological reactors

All the presumptive remedies presented above are well understood methods that have been used for many years in the treatment of drinking water and/or municipal or industrial wastewater (USEPA, 1996). A combination of any/all technologies is implied. Selection of technologies for long term treatment of extracted groundwater requires an understanding of the types of technologies that will be needed, how they will be used in the treatment system, and site-specific information for determining the most appropriate and cost-effective technologies. The presumptive technologies presented above are the technologies that will be retained for further consideration. The presumptive remedy guidance (USEPA, 1996) and its associated Administrative Record will constitute the Development and Screening of Alternatives portion of this FS.

2.5 Evaluation of Technologies and Selection of Representative Technologies

The three presumptive remedial technologies for soil (and one removal action for excavation), four in situ remedial technologies for groundwater, and the four ex situ remedial technologies for groundwater all have the same goal – to remove VOCs. Containment using engineering controls has also been evaluated. Factors specific to the region or the specific site determine whether a presumptive technology is appropriate for remediating a particular site.

2.5.1 Soil Vapor Extraction (SVE)

SVE involves the application of a vacuum through wells installed within unsaturated-zone soils (the vadose zone). Vacuum is applied to the subsurface using a vacuum blower with the suction line connected to the vapor extraction wells and the discharge line connected to a treatment system or directed to the atmosphere. The application of vacuum to the subsurface results in the flow of soil vapor to the vapor extraction wells. SVE remediates the subsurface not only by the removal of contaminated soil vapors, but also by enhanced volatilization from soil particles induced by lower subsurface pressure. Soil vapors from the extraction wells are conveyed

through piping to the vacuum blower, and are then discharged to the atmosphere with or without treatment. The benefits of the SVE technology include the following:

- SVE is a readily available, proven technology; it does not rely on site-specific geochemistry or specialized tools to implement other than standard drilling equipment, piping, and vacuum pumps.
- SVE is not dependent on the successful introduction of any amendments into the subsurface.
- SVE generates a waste stream (i.e., extracted vapors) that can be discharged to ambient air or can be easily treated with activated carbon, which can then be recycled.

The disadvantages of SVE technology include the following:

- To be most effective SVE requires high-permeability soils through which uniform vapor flow can be achieved.
- SVE is dramatically less effective within low-permeability silt and clay soils because either an extraction flow cannot be induced at all or extraction flow quickly channelizes, which may leave a large volume of the subsurface unremediated. However, vapor recovery within low-permeability sediments can generally be enhanced using pneumatic fracturing techniques.
- Low-permeability soils also typically result in a small radius of influence (ROI) around each extraction point, which then requires a high density of extraction points for effective SVE in the subsurface. Pneumatic fracturing can increase the ROI within low permeability soils.
- SVE implementation for deeper contaminated soil is limited by the cost of installing deeper wells and the greater potential for groundwater interaction with greater depth. Groundwater extraction wells (and associated groundwater treatment systems) may be required to suppress natural groundwater levels to allow proper performance of the SVE system.
- SVE implementation in a thin unsaturated zone would be compromised by an influx of atmospheric air rather than soil vapor, essentially short-circuiting the system and reducing the amount of contaminated soil vapors removed and treated by the system. This disadvantage is significantly reduced or eliminated when the ground surface is sealed, such as with asphalt pavement or concrete.

SVE is recognized as a potential remedial technology that may have application to shallow soils in the source area, but likely not in the deep groundwater plume. Site-specific conditions regarding SVE implementation in the source area include:

- Shallow soils that are comprised primarily of clay; it is well proven that the ROI is generally limited in clay. Testing will be necessary to determine the effectiveness of pneumatic fracturing techniques to increase the ROI.
- The depth to source area groundwater at the Jones Road site is approximately 20 feet and coincides with the first more permeable soil layer. Soil contamination below the water table would not be treatable with SVE without concurrent groundwater withdrawal (dewatering).
- The Bell facility shopping center has a paved parking lot over much of the ground surface, which may provide a surface seal for vacuum control.

2.5.2 Ex Situ Thermal Desorption

Ex Situ thermal desorption is applied to excavated soils and uses direct or indirect heat exchange to vaporize organic contaminants from soil, sediment, sludge, or other solid or semisolid materials. Contaminated soil is excavated and placed within an engineered ex situ vessel or lined soils pile in which heating and vapor extraction equipment is placed. Alternatively, a thermal desorption unit through which soils can be passed can be used. Vapors generated by the heating process are collected in the vapor extraction equipment and conveyed to a treatment system for removal of contaminants. The primary benefit of ex situ thermal desorption technology is that:

- It is an aggressive ex situ treatment technology that can wholly and rapidly remove a large volume of contaminant mass from soils in a single remedial event.

The primary disadvantages, however, of ex situ thermal desorption are that:

- It requires direct access to the contaminated soil and the ability to excavate and remove that material. This would require demolition of the building.
- Adjacent space must be available for soil processing; a site-specific limitation is the viability of excavating the necessary soil, processing it nearby, and replacing it.
- ARARs and/or local community concerns may not allow thermal treatment of VOCs, or meeting air emissions requirements may be impractical. The site is within an ozone nonattainment area.

2.5.3 Ex Situ Incineration

Ex Situ incineration is applied to excavated soils and is an engineered process employing thermal decomposition via oxidation at temperatures usually greater than 900 degrees Celsius (°C) to destroy the organic fraction of the waste. Contaminated soil is excavated and passed through an incinerator unit either on site or at an off-site facility. Use of an offsite facility increases costs due to transportation requirements.

The primary benefit of ex situ incineration technology is that:

- It is an aggressive ex situ treatment technology that can wholly and rapidly remove a large volume of contaminant mass from soils in a single remedial event.

The primary disadvantages, however, of ex situ incineration are:

- It requires direct access to the contaminated soil and the ability to excavate and remove that material. This would require demolition of the building.
- Adjacent space must be available for soil processing or loading for transport; a site-specific limitation is the viability of excavating the necessary soil, processing it nearby, and replacing it.
- ARARs and/or local community concerns may not allow thermal treatment of VOCs, or meeting air emissions requirements may be impractical. The site is within an ozone nonattainment area.

2.5.4 Excavation and Disposal

Excavation and transportation of soils to an off-site, permitted landfill is a removal action under consideration for shallow source area soils at the site. The primary benefits of excavation and disposal technology are that:

- It is a removal action that can wholly and rapidly remove a large volume of soils from the subsurface in a single remedial event, and minimal air emission concerns exist compared to thermal treatment.
- Loading directly from the source area for transport and disposal can shorten overall project time and minimize public exposure to contaminated soil and air emissions.

The primary disadvantages, however, of excavation and disposal are:

- It would require demolition of the building.
- It would require relocation of the current tenants of the building.

- It would pose logistical difficulties during demolition of the building, and loading/transportation of materials in a congested traffic area.

2.5.5 Bioremediation (In Situ Groundwater)

Bioremediation is an in situ groundwater treatment technology that involves using naturally occurring bacteria or designed bacterial mixes, along with groundwater amendments, to increase the rate at which contaminants are destroyed by biological degradation.

The benefits of using in situ bioremediation include:

- Bioremediation treats contaminants in situ, reducing costs, disturbances, and exposures.
- Bioremediation can be used to treat dispersed contaminants.
- Bioremediation can destroy or transform contaminants in situ, eliminating waste disposal.
- Bioremediation takes advantage of natural processes that are potentially self-sustaining to provide some residual treatment effectiveness in the applied area.
- Bioremediation provides a long term remedy for the deeper groundwater WBUs with self-sustaining potential.

The disadvantages of using in situ bioremediation include:

- Potential lack of nutrients, biological competition, immobility of introduced bacteria, preferential consumption of non-targeted contaminants, or geochemical factors.
- Excessive bacteria growth can lead to biofouling of wells or localized areas of the WBU, disrupting groundwater flow.
- Below a certain contamination level, bacteria can no longer grow by consuming the contaminant, and supplemental nutrients must be added.
- Application of designed bacterial mixes and/or supplemental nutrients may be difficult in low-permeability soils associated with the source area, and may require pneumatic fracturing.

2.5.6 Chemical Oxidation (In Situ Groundwater)

Chemical oxidation is an in situ groundwater treatment technology that has primarily been considered to address contaminants in the source area groundwater. However, in practical applications, the process treats soil and groundwater concurrently. A secondary purpose may be treatment of localized “hot spots” within relatively low concentration groundwater plumes, with potential application to deeper groundwater “hot spots”. A variety of chemical oxidants and

application techniques can be used to bring oxidizing materials in contact with contaminants to destroy them.

The benefits of using in situ chemical oxidation include:

- Chemical oxidation treats contaminants in situ, reducing costs, disturbances, and exposures.
- Chemical oxidation can be used to treat high concentrations of contaminants.
- Chemical oxidation works rapidly, enabling shortened remediation schedules.
- Chemical oxidation provides a permanent remedy for the high concentrations of contaminants with potential for near immediate results.

The disadvantages of using in situ chemical oxidation include:

- Chemical oxidation may have higher initial costs than other source area solutions.
- Injection by permanent wells is required for deeper groundwater, raising capital costs quickly with the depth of contamination.
- Low permeability soils may prevent contact between oxidants and contaminants and may require pneumatic fracturing for application of oxidants. Lower permeabilities lead to a smaller radius of influence and tighter spacing of injection points.
- Preferential flow pathways may divert oxidant away from the area of targeted contamination.
- Significant health and safety concerns are associated with applying oxidants.
- Little or no residual effectiveness as oxidants are consumed by the chemical reaction.
- May significantly alter the aquifer geochemistry, especially through precipitation of metals blocking pore spaces.

2.5.7 Monitored Natural Attenuation (In Situ Groundwater)

Monitored natural attenuation (MNA) is not considered as a stand-alone remedial alternative for in situ groundwater. However, MNA is being considered more frequently as part of remedial actions at various CERCLA sites. As stated in the USEPA OSWER guidance document *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (USEPA, 1999), USEPA does not consider MNA to be a presumptive remedy, but merely one option that should be evaluated along with other applicable remedies.

While not technically a presumptive remedy, MNA is considered and evaluated within the FS as a viable component of one or more remedial alternatives. Source control and long term performance monitoring are fundamental components of any MNA remedy (USEPA, 1999). The use of MNA differs from a no-action alternative as it is expected that under an MNA remedy performance monitoring will continue until the remediation objectives have been achieved, and longer if necessary to verify that contaminants no longer pose a threat to human health and/or the environment.

Natural attenuation is the name given to the combination of natural processes occurring at a site that result in a decrease in the concentration of a COC, with time or distance from a source. Natural attenuation mechanisms can be classified as either destructive or nondestructive. Destructive mechanisms actually remove the parent compound from the environment by breaking it down into one or more simpler compounds. Nondestructive mechanisms generally transfer the parent compound from one environmental medium into another or spread the parent compound over a greater volume of the same environmental medium. The most common destructive natural attenuation mechanism is biodegradation. Nondestructive mechanisms include dilution, dispersion, advection, sorption, and volatilization.

The benefits of MNA include the following:

- MNA does not require the installation of infrastructure other than a network of monitoring points.
- MNA does not rely on any amendments to the subsurface.
- There is no operations and maintenance (O&M) associated with MNA other than sampling costs and monitor well maintenance, and no waste stream other than purge water is generated during sampling events.

The disadvantages of MNA include the following:

- MNA has limited ability to remediate high concentrations in groundwater.
- MNA requires additional testing parameters, raising the cost of sample analysis above other options.
- Even under good conditions, MNA often takes a longer time to achieve PRGs versus other more aggressive remedies.
- MNA is limited by naturally existing physical, biological, and geochemical processes. Native geochemical and biological conditions may or may not be sufficient to completely

reduce the contaminant source. In such conditions, MNA relies solely on the slower physical processes of diffusion and dispersion.

Site-specific uncertainties regarding MNA implementation at the Jones Road site include:

- The existence of appropriate native microbiological populations to support bioremediation of the COCs and the effectiveness and rate of such biologically-mediated attenuation
- The existence of geochemical conditions that are favorable to support biologically mediated attenuation of COCs
- The rate of the physical properties of dispersion and diffusion

2.5.8 Containment (Groundwater)

In situ groundwater containment is not a treatment technology, but is an engineering control used to prevent or slow down the movement of contaminants. A variety of containment techniques can be used to reduce mobility of contaminants or prevent migration. Containment may be a passive technique to slow or stop the migration of groundwater or other liquids (slurry wall, grout wall, or impermeable membrane). Hydraulic containment/pump and treat is a technique used to reverse the groundwater flow direction with direct or indirect manipulation of the groundwater table (extraction wells, injection wells, drains).

The benefits of using containment include:

- Containment mitigates migration of contaminants, reducing exposure area.
- Containment can be used to immobilize high concentrations of contaminants.
- Containment works rapidly, enabling shortened active remediation schedules.
- Containment can be used to reduce mobility of contaminants or prevent migration. This control can be used to limit the application of other remedial technologies to smaller areas or volumes.

The disadvantages of using containment include:

- Containment may have higher initial costs than other source area solutions.
- There is no direct treatment or reduction in concentration of the contaminants.
- It may significantly alter aquifer flow patterns, potentially disturbing natural patterns, and potential affecting existing water supply wells in the same WBU.

- For hydraulic containment, a large volume of water may be produced that would require treatment and/or disposal.

2.5.9 Air Stripping (Ex Situ Groundwater)

Air stripping removes VOCs from groundwater by passing ambient air through the groundwater to strip the VOCs from the groundwater into the gaseous phase. Air stripper off gas will still require treatment and for the purpose of the FS is expected to be passed through a granular activated carbon (GAC) filter or thermal destruction device prior to discharge to the atmosphere.

The benefits of air stripping include:

- Air stripping does not require chemical additives for operation.
- Air stripping is the simplest process of the presumptive technologies; air stripping can be used to remove VOCs from groundwater with minimal complexity.
- Air stripping is inexpensive relative to the other presumptive technologies.

The disadvantages of air stripping include:

- Air stripping produces an air waste stream that may require monitoring or separate treatment; the site is within an ozone nonattainment area.
- Stripped VOCs may be treated with GAC or a thermal destruction device.
- Effectiveness varies with temperature and contaminant concentrations, potentially requiring cycle time adjustments.
- Air stripping towers may be prone to fouling problems.
- Air strippers may require special siting considerations due to surrounding residential areas.

2.5.10 Granulated Activated Carbon (Ex Situ Groundwater)

Granular activated carbon (GAC) removes VOCs from groundwater by adsorption of VOCs onto the GAC. After the GAC has become saturated, it must be recycled or disposed, and replaced with fresh GAC.

The benefits of GAC include:

- GAC does not require chemical additives for operation.
- GAC produces no gaseous phase waste stream.

- GAC is simpler than chemical oxidation or biological reactors.
- The application of GAC can reliably remove VOCs from groundwater with one-step processing.

The disadvantages of GAC include:

- Costs of replenishing, recycling, and disposing GAC (Bureau of Reclamation [BR], 1999)

2.5.11 Chemical Oxidation (Ex Situ Groundwater)

Chemical oxidation removes VOCs from groundwater by oxidizing the VOCs into non-hazardous breakdown products. The benefits of chemical oxidation include:

- No hazardous waste streams to monitor or dispose
- Chemical oxidation can be used to move VOCs from groundwater in a fast, flexible, and reliable way.

The disadvantages of chemical oxidation include:

- Complex process with active chemical reactions
- High cost of chemicals required for reactions (BR, 1999)
- Highly corrosive to process equipment and potentially reactive with non-targeted chemicals

2.5.12 Ultraviolet Oxidation (Ex Situ Groundwater)

Ultraviolet (UV) oxidation removes VOCs from groundwater by generating ozone from UV light applied to water, which then oxidizes the VOCs into non-hazardous breakdown products.

The benefits of UV oxidation include:

- No hazardous waste streams to monitor or dispose
- UV oxidation is simpler than biological and chemical reactors.
- UV oxidation can be used to remove VOCs from groundwater with no chemical handling.

The disadvantages of UV oxidation include:

- High cost of electricity to make UV to create ozone required for reactions (BR, 1999)
- Highly corrosive to process equipment and potentially reactive with non-targeted chemicals

2.5.13 Aerobic Biological Reactors (Ex Situ Groundwater)

Aerobic biological reactors remove VOCs from groundwater by biologically assisted breakdown of VOCs into new organic compounds by means of biological processes, generally by the action of microorganisms. Complete degradation reduces VOCs to non-hazardous chemicals such as carbon dioxide and chloride.

The benefits of aerobic biological reactors include:

- Continuous operation
- No hazardous waste streams
- Aerobic biological reactors can be used to remove VOCs from groundwater by complete degradation to non-hazardous chemicals.

The disadvantages of aerobic biological reactors include:

- Solid waste in the form of wastewater sludge needs handling and disposal.
- Large footprint
- High capital cost of equipment and electricity (BR, 1999)

3.0 Development of Alternatives

This section provides an overview of the remedial alternatives developed to meet the RAOs and PRGs for the Jones Road site in consideration of ARARs and the presumptive remedy technology options described in **Section 2**. It includes a description of the assumptions made in defining each alternative, as well as a description of the proposed components of each alternative. These assumptions and components provide the basis for the cost estimates developed for each alternative under the comparative analysis described in **Section 4**. The comparative analysis provided in **Section 4** discusses each alternative in terms of effectiveness, implementability, and cost.

Preliminary design field investigations will be needed to gain information about the hydraulic characteristics of the numerous subsurface layers and other design parameters. Determining unknown screen depths of inactive water wells will help refine deep groundwater contamination patterns. Measuring hydraulic conductivity and transmissivity at various locations and depths in the deeper groundwater will help solidify design decisions for groundwater in situ technology alternatives. The lack of information about VOC concentrations in groundwater from 50 to approximately 100 feet bgs will be addressed by adding monitor wells in this depth range at appropriate locations.

Institutional controls to prevent human exposure to contaminants in soil would consist of land use restrictions for the source area where contaminants are present in surface and shallow subsurface soil. Land use in the source area would be restricted to commercial/industrial uses, impermeable pavement would be required over soil with high contaminant concentrations, and construction standards to limit soil contact and ensure proper disposal and handling of soil would be required. The property at 11600 Jones Road is the primary expected target for land use deed restrictions to be applied.

Groundwater use restrictions or restrictive covenants would have to be implemented on a property by property basis or through a blanket groundwater use restriction implemented over some larger area. With the current extent of the plume, that area would likely be all the properties within the limits of the Harris County "No New Wells" area, and the TDLR restricted water well drilling area (**Figure 16**). These areas could be combined to form a designated area where new groundwater wells in the Chicot Aquifer would not be allowed for human consumption or contact uses, and specific protective construction techniques would be required for any deeper wells installed. The recent completion (November, 2008) of a drinking water supply line into the area to provide potable water for area residents makes groundwater use restrictions a feasible alternative.

The investigations to date have not been intended to evaluate MNA potential at the Jones Road site. Sample results have generally not shown identifiably decreasing concentration trends, and the test results needed for evaluating supporting lines of evidence have not been collected. Because evidence of MNA is lacking, and VOC concentrations in the shallow groundwater (less than 50 feet bgs) are higher than reasonably addressable by MNA, MNA alone cannot be considered as a remedial alternative for the source area. However, MNA may be applied to eliminating lower VOC concentrations in the deeper groundwater. At some point in the future, MNA may also be used in lieu of applying aggressive treatment alternatives to low remnant VOC concentrations in shallow groundwater.

As remediation proceeds at the Jones Road site, there will be opportunities to sample and test parameters to evaluate MNA potential effectiveness. During future USEPA and TCEQ 5-year reviews MNA may be evaluated, and if evidence of MNA is sufficiently strong, MNA may be implemented at the Jones Road site to replace continuing aggressive and expensive treatment.

3.1 Selecting Technologies

Remedial alternatives were developed by choosing appropriate technologies from among those discussed in Section 2. Although all the technologies discussed have proven themselves to be applicable for remediating the COCs present (VOCs), some of the technologies are not expected to be effective at the Jones Road site. Others, while potentially effective, were not deemed sufficiently efficient for serious consideration.

3.1.1 Soil Technologies

Soil vapor extraction (SVE) is not retained as a soil remediation technology because of the difficulties of applying SVE to clays. It is anticipated that SVE cannot be readily designed to provide sufficiently effective treatment of COCs within the unsaturated soil in the source area, which is mostly clay, without incorporating techniques such as pneumatic fracturing and horizontal vapor extraction wells.

Ex situ thermal desorption and incineration are not retained as soil remediation technologies because of the difficulties involved in handling COC contaminated soil in a developed residential and commercial neighborhood. A site-specific limitation is the viability of excavating the necessary soil, processing it nearby, and replacing it. Significant contamination is present beneath the facility, and demolition of the building and relocating the current tenants is considered impractical.

Excavation is not retained as a soil remediation technology because of the traffic impacts and difficulties involved in handling COC contaminated soil in a developed residential and commercial neighborhood. Excavating the soil for loading and disposal would expose the

neighborhood to contaminated soil for a lesser time period than the ex situ thermal desorption or ex situ incineration, but the traffic impacts of loading and transporting excavated soil to a permitted landfill would be disruptive to the neighborhood over a wider area. Demolition of the building would be required and relocating the current tenants is considered impractical.

Chemical oxidation is retained as a soil remediation technology because it is effective, fast, and minimally disruptive. Chemical oxidation can be used to effectively treat the high COC concentrations in unsaturated soil. The oxidation reaction proceeds quickly, shortening remediation schedules and evaluation times. Oxidants applied to soil by direct injection are minimally disruptive compared to the other technologies.

3.1.2 In Situ Groundwater Technologies

Bioremediation is retained as a groundwater remediation technology for deep groundwater, but not for shallow groundwater. The deep groundwater (more than 50 feet bgs) zones have relatively high permeability, which allows delivery of nutrients and bioaugmentation mixtures. Bioremediation provides a long-term remedy with the potential to be self-sustaining in the deep groundwater zones. The high concentrations of dissolved PCE found in the shallow groundwater (less than 50 feet bgs) may be more efficiently addressed by chemical oxidation. The low permeability of the shallow groundwater zone restricts the ability to deliver nutrients and bioaugmentation mixtures to the targeted COCs.

Chemical oxidation is retained as a groundwater remediation technology for shallow groundwater, but not for deep groundwater. Chemical oxidation can be used to effectively treat the high COC concentrations in the shallow groundwater (less than 50 feet bgs). The oxidation reaction proceeds quickly, shortening remediation schedules and evaluation times. Oxidants applied to shallow groundwater by direct injection are minimally disruptive. To apply chemical oxidation to the deep groundwater (more than 50 feet bgs) would require the use of permanent wells, whether existing or newly installed. The relatively low concentrations of PCE in the deep groundwater would cause most of the oxidants to react with other dissolved chemicals or solids in the WBU, potentially altering the aquifer chemistry and inhibiting natural attenuation mechanisms.

Monitored natural attenuation (MNA) is retained as a supplemental groundwater remediation technology for both shallow groundwater (less than 50 feet bgs) and deep groundwater (more than 50 feet bgs). Although considerable uncertainties exist, the ease of implementation and the fact that no additional treatment infrastructure is needed make consideration of this technology viable.

Physical containment is not retained as an engineering control for groundwater. For the shallow groundwater (less than 50 feet bgs), physical containment is not possible, since there is no practical method for installing a horizontal barrier below the source area to prevent downward migration of contaminants, and the pattern of groundwater contamination indicates that COCs have already migrated vertically to depths of more than 200 feet and spread well beyond the source area. Physical containment would do nothing to address this past and potential future vertical migration. For the deep groundwater (more than 50 feet bgs), physical containment is technically difficult and uneconomical due to the greater depths involved (more than 200 feet bgs).

Hydraulic containment/pump and treat is retained as an engineering control for groundwater. For the shallow groundwater (less than 50 feet bgs) the plume extent is small and the permeability of the formation is relatively low. Additional testing of the shallow groundwater formation hydraulic properties will be required to determine the applicability and design requirements for hydraulic containment/pump and treat. For the deep groundwater (more than 50 feet bgs) the plume extent is much larger and the formation is much more permeable. Groundwater modeling (**Appendix B**) has indicated that hydraulic containment/pump and treat can be established with a network of multiple wells. Groundwater extracted to provide hydraulic containment/pump and treat would require treatment.

3.1.3 Ex Situ Groundwater Technologies

Air stripping was retained as an ex situ groundwater remediation technology. Groundwater extracted for hydraulic control may require treatment prior to discharge. Air stripping is the simplest process of the presumptive technologies, and has the lowest expected cost per volume of treated water.

GAC was not retained as a sole ex situ groundwater remediation technology, but it is retained for polishing the air and water following air stripping. GAC, chemical oxidation, ultraviolet oxidation, and aerobic biological reactors offer no substantial advantage over the less expensive presumptive technology of air stripping.

3.2 Alternatives Developed

Based on the presumptive remedy technologies presented in Section 2, site information from past investigations, *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (USEPA, 1993), *Frequently Asked Questions Regarding Management of Chlorinated Solvents in Soils and Groundwater* (ESTCP, 2008), and the discussion in previous Section 3.1, the following preliminary remedial alternatives have been developed to address contaminants in groundwater at the Jones Road site:

1. No Further Action;
2. In Situ Treatment;
3. Hydraulic Containment/Pump and Treat; and
4. In Situ Enhancements to Pump and Treat.

Table 3 provides a side by side comparison of these alternatives and the following sections provide more detailed discussion of each alternative.

3.3 Detailed Analysis of Alternatives

3.3.1 Alternative 1 – No Further Action

The No Further Action alternative constitutes the absence of any remedial actions.

3.3.1.1 Description

Under this alternative, no measures would be taken to address soil or groundwater contamination, and no measures would be taken to prevent human exposure to them.

3.3.1.2 Detailed Analysis

No Further Action is considered in this evaluation as a baseline for comparison to all other potential remedial actions, as required by the NCP.

3.3.2 Alternative 2 – In Situ Treatment

The in situ treatment alternative would involve treating the soil and groundwater without removing them. The treatments would be as recommended in the Final Treatability Study Report (**Appendix A**). The treatability study evaluated in situ chemical oxidation (ISCO), biostimulation, bioaugmentation, and zero valent iron (ZVI) as potential treatments. Treatment of the source area soil and groundwater with permanganate was recommended, along with bioaugmentation with lactate for deeper groundwater. **Figure 17** shows the expected in situ treatment areas.

3.3.2.1 Description

Institutional controls as described in the introduction to **Section 3.0** would be implemented. ISCO would be applied to contaminated soil and groundwater in the source area. A pilot study will be conducted to determine which in situ treatment will be most effective and appropriate for the source area soil and groundwater and the deep groundwater plume. For cost estimating purposes, it is assumed that ISCO will be chosen for source area groundwater and bioaugmentation will be chosen for the deep groundwater plume.

ISCO would be applied to soil and shallow groundwater in the source area to destroy source area contaminants. Permanganate solution has been used for quantity and cost estimating purposes. Chemical oxidant would be injected through approximately 144 temporary injection sites to 50

feet bgs, spaced 20 feet apart, to treat the 160 by 320 foot area shown on **Figure 17**. It is anticipated that two applications of permanganate would be made to the shallow soils and groundwater. Injections would be made from the outside in and from the bottom up to minimize horizontal and vertical induced migration caused by fluid displacement.

Bioaugmentation would be applied to hot spots within the deeper zones of groundwater to both destroy contaminants and enhance natural attenuation of contaminants. Monitor wells deeper than 260 feet bgs do not have detectable PCE concentrations. The number of water wells with PCE concentrations above the MCL in February 2008 was 41. The 10 most contaminated of these water wells would have bioaugmentation applied. Further applications of bioaugmentation (both in timing and choice of wells) would depend on the results of ongoing monitoring results. It is anticipated that four applications of bioaugmentation would be applied to the 10 most contaminated water wells, with at least one year between applications.

Groundwater monitoring would be quarterly for the first two years, and semiannually for years 3 through 5. This would be reduced to annual sampling if data trends show enough stability to permit the reduction. After an additional 10 years of annual sampling (10 rounds), this would be reduced to sampling once every 5 years if data trends show enough stability to permit the reduction.

3.3.2.2 Detailed Analysis

Preliminary design field investigations needed for this alternative include:

- Hydraulic testing (slug test) to determine the hydraulic properties of the shallow groundwater;
- Hydraulic testing (slug test) of deeper groundwater zones;
- Pilot study to determine injection radius of influence and effectiveness of in situ ISCO and bioaugmentation treatments; and
- Determining screen depths for inactive wells with unrecorded screens.

At the anticipated permanganate application rate to saturated soil a total of 2,800 kg of permanganate would be applied to the source area soil and groundwater by direct injection. Direct injection (jet grouting) is a commercial technology that is readily available and recommended for the application of permanganate.

Bioaugmentation would be applied through existing inactive water wells with the permission of the well owner. The well owners who signed the TCEQ water line agreement relinquished control of their water wells to the TCEQ. These wells would be considered first for

bioaugmentation. Some adaptation of the well plumbing would be necessary to inject bioaugmentation solution through the existing wells.

For performance monitoring, a reduced number of water wells would be sampled, although the wells sampled may vary from event to event. The 19 existing monitor wells would be sampled along with a representative selection of 31 private water wells (50 total). Water wells in each depth category would be sampled with wells both within the plume and outside the plume selected for sampling. During the remedial design, a formal list of wells to sample would be selected. **Table 4** lists some of the wells to consider for sampling. All samples would be tested for VOCs to track plume concentrations and limits. A subset of 20 wells would be tested for MNA indicator parameters (e.g., pH, TOC, ORP, DO, sulfate/sulfide, nitrate/nitrite, carbon dioxide, ferrous iron, alkalinity, and bacterial community) during the quarterly sampling events to help evaluate the bioaugmentation treatments and MNA performance.

3.3.3 Alternative 3 – Hydraulic Containment/Pump and Treat

The hydraulic containment/pump and treat alternative would involve pumping groundwater from the subsurface in both the source area (less than 50 feet bgs) and the deeper groundwater zones at high enough rates to prevent further migration of PCE in groundwater. The pumped groundwater would then be treated to remove VOCs. Alternative 3 does not directly address soil; although, some remediation of soils is expected as a result of pumping. **Figure 18** shows the expected locations of extraction wells for hydraulic containment/pump and treat within the deeper groundwater zones.

3.3.3.1 Description

Institutional controls as described in the introduction to **Section 3.0** would be implemented. For the shallow groundwater at the source area (less than 50 feet bgs), and depending upon hydraulic properties to be determined during the design phase, contaminated groundwater would be extracted at MW-1 and MW-6 to hydraulically control the migration of PCE contaminated groundwater. The extracted groundwater would be treated by air stripping to remove the PCE and the treated groundwater would be reinjected into the source area groundwater or disposed through the local sanitary sewer system or to an outfall under TPDES permit.

For deeper groundwater, the plume appears to have traveled differentially due to the nature of sand/clay packages and local groundwater withdrawal rates. Hydraulic containment/pump and treat wells would need to be placed to intercept the plume accordingly (**Figure 18**). A total of 6 deep extraction wells would be needed, each with an extraction rate of 20 gpm at each well, for a total extraction rate of 120 gpm (**Appendix B**).

The extracted groundwater would be treated by air stripping to remove PCE contamination and the air waste stream would be run through GAC for polishing if necessary to prevent public exposure to PCE by inhalation.

Treated groundwater would be released to the HCFCD drainage ditch, contingent on approval, discharged to sanitary sewer and POTW, if available, or reinjected into the WBU to offset potential subsidence. For the purpose of estimating costs, reinjection into the deep groundwater is assumed using six injection wells.

Groundwater monitoring would be quarterly for the first two years, then semiannually for years 3 through 5. Monitoring may be reduced to annual sampling if data trends show enough stability to permit the reduction. After an additional 10 years of annual sampling, this would be reduced to sampling once every 5 years if data trends show enough stability to permit the reduction.

3.3.3.2 Detailed Analysis

Preliminary design field investigations needed for this alternative include:

- Hydraulic testing (slug test) of shallow groundwater zones;
- Hydraulic testing (slug test) of deeper groundwater zones;
- Startup testing of air stripper treatment system; and
- Determining screen depths for inactive wells with unrecorded screens.

In the past, intermittent pumping from water wells may have served to hydraulically contain or partially contain the groundwater plume in deeper groundwater. With completion of the water line in November 2008 and subsequent reduced pumping of groundwater, plume containment may be lessened. The *Simple Capture Zone Modeling* (**Appendix B**) indicates six wells in the Chicot Aquifer pumping at 20 gpm may be enough to establish hydraulic control of the deeper groundwater plume.

Pumping deep groundwater for hydraulic containment/pump and treat would generate approximately 120 gallons per minute according to the *Simple Capture Zone Modeling* (**Appendix B**). This pumping rate might be large enough that the Harris-Galveston Subsidence District would object to this strategy. Reinjection of the treated groundwater may offset this concern. The groundwater pumped out would have to be treated before release or reinjection. The amount of groundwater generated by hydraulic control in the shallow source area (less than 50 feet bgs) is expected to be negligible by comparison.

The air stripping/GAC treatment system would be broken into two parts, one east of Jones Road and one west of Jones Road. The open space behind (east of) the Cypress Shopping Center

might serve as a location for the east treatment system. Open space along the south side of Tower Oaks Boulevard might serve as a location for the west treatment system.

Reinjection of treated groundwater might be used to mitigate or reduce subsidence caused by groundwater extraction. Reinjection of waste water from a Superfund site, (even if cleaned to concentrations below the laboratory detection limit) may not be permissible into a Class 1 drinking water aquifer. Reinjection of water will also require added energy consumption and additional operational costs associated with mechanical upkeep of injection wells, and reinjection of groundwater can also cause changes in groundwater flow patterns. The six injection wells may be installed upgradient of the deep groundwater plume for enhanced flushing of contaminants, or downgradient of the plume for increased hydraulic control. Locations of injection wells will be selected during remedial design. Reinjecting treated groundwater to the deeper WBUs would require effluent discharge monitoring. Effluent testing on a monthly basis is assumed for purposes of the cost estimate. Recommended testing would likely include VOCs, semivolatile organic compounds (SVOCs); biochemical oxygen demand (BOD); pH; TOC; total kjeldahl nitrogen (TKN); ammonia nitrogen (AMN); nitrate and nitrite; total phosphorus; total suspended solids (TSS); oil and grease; and chemical oxygen demand (COD). As treated groundwater would likely have relatively homogenous characteristics, the cost estimate assumes monthly testing for wastewater discharge characteristics would be sufficient.

Direct release of treated groundwater to a HCFCD drainage ditch would require approval from Harris County. Previously, this approval could not be obtained for disposal of well production water. For this reason, discharge to a HCFCD ditch is not expected and is not reflected in the cost estimates.

Release by discharging to a sanitary sewer to a POTW (if available) would require identifying a POTW willing to accept the water. The Jones Road site is largely served by individual septic systems, so there may be no simple way to discharge directly to a sanitary sewer. Discharge to a sanitary sewer is not expected, and is not reflected in the cost estimates.

The performance of hydraulic containment/pump and treat would be monitored through routine groundwater sampling. A reduced number of water wells would be sampled, although the wells sampled may vary from event to event. The 19 existing monitor wells would be sampled along with a representative selection of 31 private water wells (50 total). Water wells in each depth category would be sampled with wells both within the plume and outside the plume. **Table 4** lists some of the wells to consider for sampling. During the remedial design, a formal list of wells to sample would be selected. All samples would be tested for VOCs to track plume concentrations and limits. A subset of 20 wells would be tested for MNA indicator parameters (e.g., pH, TOC, ORP, DO, sulfate/sulfide, nitrate/nitrite, carbon dioxide, ferrous iron, alkalinity, and bacterial community) during the quarterly sampling events to help evaluate MNA

performance. Results would be used to verify hydraulic containment/pump and treat and evaluate the success of the hydraulic containment/pump and treat system.

3.3.4 Alternative 4 – In Situ Enhancements to Pump and Treat

In situ enhancements to the pump and treat alternative would involve pumping groundwater from the subsurface in both the source area and the deeper groundwater zones. Chemical or bioremediation enhancements would be added through injection wells to enhance destruction of PCE in the soil and groundwater. **Figure 19** shows possible locations of extraction wells and in situ enhancements.

3.3.4.1 Description

This alternative is substantially similar to Alternative 3 with the addition of in situ enhancement such as that described in Alternative 2. Institutional controls as described the introduction to **Section 3.0** would be implemented. In situ treatment would be applied to soil and groundwater in the source area (less than 50 feet bgs).

ISCO would be applied to soil and shallow groundwater in the source area to destroy source area contaminants. This activity would be performed as described in Alternative 2.

Bioaugmentation would be applied to the deeper zones of groundwater with lower PCE concentrations to both destroy contaminants and enhance natural attenuation of contaminants. This activity would be performed as described in Alternative 2.

Pumping of groundwater for hydraulic control and treatment would be performed as described in Alternative 3, with exceptions made for periods of in situ treatment application to allow time for the applied treatments to effectively destroy contaminants. It is anticipated that hydraulic containment/pump and treat of the source area shallow groundwater (less than 50 feet bgs) will be unnecessary after ISCO application to the area.

Groundwater monitoring would be quarterly for the first two years, then semiannually for years 3 through 5. Monitoring may be reduced to annual sampling if data trends show enough stability to permit the reduction. After an additional 10 years of annual sampling, this would be reduced to sampling once every 5 years if data trends show enough stability to permit the reduction.

3.3.4.2 Detailed Analysis

Preliminary design field investigations needed for this alternative include:

- Hydraulic testing (slug test) to determine whether shallow groundwater is a WBU;
- Hydraulic testing (slug test) of deeper groundwater zones;

- Pilot study to determine injection radius of influence and effectiveness of in situ ISCO and bioaugmentation treatments;
- Startup testing of air stripper treatment system; and
- Determining screen depths for inactive wells with unrecorded screens; and

Refer to Sections.3.3.2.2 and 3.3.3.2 for a detailed analysis of Alternative applications.

4.0 Detailed Analysis of Alternatives

A detailed analysis of alternatives consists of the following activities:

- Defining each alternative further, if necessary, with respect to the volumes or areas of contaminated media to be addressed, the technologies to be used, and any performance requirements associated with those technologies.
- Assessing and developing a summary profile of each alternative against the nine evaluation criteria.
- Conducting a comparative analysis of the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion (USEPA, 1988).

This approach is designed to provide sufficient information to adequately compare the alternatives and to provide the basis for selecting an appropriate remedy for the Jones Road site pursuant to CERCLA remedy selection requirements.

4.1 Evaluation Criteria

Seven of the nine evaluation criteria defined by the NCP were used to evaluate technical and policy considerations important for selecting a remedial alternative for the Jones Road site. The eighth criteria (State Acceptance), and ninth criteria (Community Acceptance), will be evaluated following receipt of comments from the State and community.

Overall protection of human health and the environment. Under this criteria, the alternatives are assessed to determine whether they can adequately protect human health and the environment, in both the short and long term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants by eliminating, reducing, or controlling exposures to levels established during the development of remediation goals, consistent with 40 CFR Section 300.430(e)(2)(i). The assessment for these criteria draws on the assessments of other evaluation criteria, particularly long term effectiveness and permanence, short term effectiveness, and compliance with ARARs.

Compliance with ARARs. The alternatives are assessed to determine whether they attain ARARs under federal, state, or local environmental laws, or provide grounds for invoking a waiver.

Long Term Effectiveness and Permanence. Alternatives are assessed for the long term effectiveness and permanence they provide, as well as for the degree of certainty that the alternative will prove successful. Factors considered as appropriate include the following:

a) Magnitude of residual risk remaining from untreated waste or treatment residuals that remain after remedial activities have been completed. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their TMV and their propensity to bioaccumulate.

b) Adequacy and reliability of controls that are necessary to manage treatment residuals and untreated waste. This factor addresses in particular the uncertainties associated with on-site land disposal for providing long term protection from residuals, the assessment of the potential need to replace technical components of the alternative, and the potential exposure pathways and risks posed should the remedial action need replacement.

Reduction of TMV through Treatment. The alternatives are assessed to determine the degree to which they employ recycling or treatment that reduces toxicity, mobility, or volume (TMV). In addition, the alternatives are assessed to determine how treatment is used to address the principal threats posed by the Jones Road site. Source area soil contaminated with PCE and shallow groundwater (less than 50 feet bgs) with high PCE concentrations constitute the principal threat waste at the Jones Road site. Factors that are considered as appropriate include the following:

a) The treatment processes the alternatives employ and the materials they will treat.

b) The amount of hazardous substances, pollutants, or contaminants that will be destroyed or treated.

c) The degree of expected reduction in TMV of the waste due to treatment and the specification to which reduction(s) are occurring.

d) The degree to which the treatment is irreversible.

e) The type and quality of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate hazardous substances and their constituents.

f) The degree to which treatment reduces the inherent hazards posed by principal threats at the Jones Road site. The NCP establishes an expectation that the USEPA will use treatment to address the principal threats posed by a site wherever practicable (NCP §300.430(a)(1)(iii)(A)). The principle threat concept is applied to the characterization of source materials at a Superfund site. A source material is material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to groundwater, surface water, or air, or acts as a source for direct exposure. Contaminated groundwater

generally is not considered to be a source material; however, the high concentrations of dissolved PCE in the source area may be viewed as source material because they approach the PCE solubility concentration. Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to human health or the environment should exposure occur.

Short Term Effectiveness. The short term effects of alternatives are assessed considering the following:

a) Short term risks that might be posed to the community during implementation of an alternative.

b) Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures.

c) Potential environmental effects of the remedial action and the effectiveness and reliability of mitigative measures during implementation.

d) Time until protection is achieved.

Implementability. The ease or difficulty of implementing the alternatives is assessed by considering the following types of factors as appropriate:

a) Technical feasibility, including the technical difficulties and the unknowns associated with the construction and operation of a technology, the reliability of the technology, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

b) Administrative feasibility, including the activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for offsite action).

c) Availability of services and materials, including the availability of adequate offsite treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment, specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and the availability of prospective technologies.

Cost. The types of costs that are assessed include the following:

a) Capital costs, including both direct and indirect costs.

b) Annual operations and maintenance (O&M) costs.