Independent Design Review: Grants Chlorinated Solvents Plume Superfund Site Grants, Cibola County, New Mexico EPA Region 6

Report of the Independent Design Review
Site Visit Conducted at the Grants Chlorinated Solvents Plume Superfund Site
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Revised Report
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NOTICE

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EXECUTIVE SUMMARY

An Independent Design Review (IDR) involves a team of expert hydrogeologists and engineers that are independent of the site, conducting a third-party peer review of remedy selection, remedy design, or re-design of an existing remedy. It is a broad review that considers the goals of the remedy, site conceptual model, available site data, performance considerations, protectiveness, cost-effectiveness, and closure strategy. The review includes reading site documents, visiting the site for one day, discussing the site with the site team, and compiling a report that includes findings and a discussion regarding remedial options and/or items for consideration during design. Consideration is given to stakeholder input to the degree that input is provided in site documents or during interviews with the site team, but because the review is technical in nature, no separate meetings are held with each stakeholder. The purpose of the review is to gain a thorough understanding of the site conceptual model and drivers for the site and to provide findings and analysis that are of value to the site team in making decisions regarding remedy selection and design. The findings and analysis presented in the IDR report are based on the information provided and the discussions with the site team and could change if additional information were made available. Because of the limited scope of the IDR process, the information used in the analysis is assumed to be accurate unless errors in the information are discovered during the IDR. The IDR is intended to be a constructive process and is not intended to criticize past actions or to simply document site details.

The findings are the opinions of the IDR team and the discussion is intended to help the site team identify opportunities for improvements. In many cases, further analysis, beyond that provided in the IDR report, may be needed prior to implementing items presented in the discussion. The considerations provided in the IDR report are the opinions of the IDR team and do not constitute requirements for future action, but rather are provided for the consideration by the Region and other site stakeholders.

The Grants Chlorinated Solvents Plume Superfund Site in Grants, Cibola County, New Mexico was selected by EPA OSRTI based on a nomination from EPA Region 6. The remedy is in the early design stage and has an estimated cost of $29.5 million. Several pre-design activities, including additional subsurface investigation and pilot tests, are ongoing and will be evaluated prior to the preliminary design (expected Fall/Winter 2008) and the final design. Results from activities conducted after the IDR site visit are not included in this report and are reserved for future discussion between the IDR team and the site team.

The IDR team notes some of the following findings and interpretations regarding the site conceptual model and remedial strategy to date.

- Ground water is present beneath the site in thin (approximately 1 foot thick) sand and silt lenses within competent clay. A relatively long, continuous lens with a thickness of approximately 1 foot is present approximately 8 feet to 16 feet bgs. Water quality data suggest that the highest concentrations and most significant horizontal transport of site-related contamination occur within this lens.

- A ground water concentration of tetrachloroethene (PCE) as high as 3,400 ug/L was detected as deep as 60 feet during direct-push sampling. Limited data at the site suggest an upward hydraulic gradient, which means that dense non-aqueous phase liquid (DNAPL) was likely present as free product at one point to allow for substantial vertical contaminant migration.

- The abundance of silt and clay in the subsurface, the presumed vertical migration of contamination through these low permeability materials, and the age of the plume (perhaps dating back to the 1970s), suggests to the IDR team that aquifer restoration could be diffusion limited, resulting in a longer than expected time frame for remediation.

- Ground water data suggest to the IDR team that the majority of contamination may have already migrated from the source area.

- Lithologic and water quality data with depth is limited.

- Concentrations of trichloroethene and cis-1,2-dichloroethene (PCE degradation products) are 10 times higher near the Allsup underground storage tank site than elsewhere in the plume indicating the hydrocarbons in the subsurface are providing a food source for microbes in the area and promoting reductive dechlorination. However, concentrations of vinyl chloride are not as high, suggesting that reductive dechlorination is not complete and that bioaugmentation (i.e., introducing appropriate microorganisms) may be appropriate.

- Limited soil data to date indicate that the area and volume for source remediation is likely much smaller than indicated in the Record of Decision (ROD), and the smaller volume for remediation may change the cost-effectiveness of some remedial options that have a high capital cost component.

- Because of contaminant migration and perhaps limited water quality and lithologic information with depth, the zone defined as the source area and targeted for thermal remediation does not appear to coincide with the zone of highest detected contamination and vertical migration. The zone that seems more appropriate based on existing data for source zone remediation appears to be on the downgradiet portion of the Holiday Cleaners property, First Avenue, and properties downgradient of First Avenue.

- The site team prefers a source area remedy that allows Holiday Cleaners to continue operating. If the area requiring source area treatment is actually downgradient of the building and parking lot, then this may be feasible. However, if thermal treatment is required beneath and immediately around the property, this may be logistically difficult both during construction and operation due to the small property and the limited access to customers.

- Other options for source area remediation discussed in the ROD and Feasibility Study include limited excavation followed by in-situ chemical oxidation (ISCO) with enhanced reductive dechlorination (ERD) polishing or ERD alone. Injections of oxidants or nutrients will preferentially enter the sand lenses, which occupy only a percentage of the aquifer volume within the source area. As a result, the amount of oxidant and nutrient required may have been significantly overestimated by using the entire volume of the source area.

- Based on the finding that only a portion of the Holiday Cleaners site is contaminated and the role of the sand lenses in controlling oxidant/nutrient delivery, the IDR team believes that the effective volume of the <u>source area</u> that would be treated by ISCO or ERD would be almost an order of magnitude smaller than the volume assumed in the Feasibility Study. Based on available data, the amount to be injected and the number of injection points may therefore be high by almost an order of magnitude if all other factors remain unchanged.

- The assumed treatment depth for the shallow plume core and hot spot is from 8 feet to 20 feet, and the injection of oxidants and nutrients is based on the total pore volume for this depth interval. However, the majority of the mass and ground water flow appears to be in a thin sand lens that is approximately 0.5 to 1 foot tick. As a result, the injection quantities needed may be an order of magnitude lower than what the site team has calculated if all other parameters and assumptions remain unchanged.

- The IDR team notes that diffusion of contaminant mass out of the lower permeability layers over time (as is assumed by the site team for the source area) may also contribute to extending remedy time frames in the shallow plume core and hot spot such that the remedial time frame might be longer than the 5 to 6 year time frame that is estimated for the ISCO/ERD approach.

- The results and lessons learned from the pre-investigation and the pilot tests may help better estimate the volumes that require treatment and the amount of oxidant or nutrient that is appropriate. The IDR team believes that the findings from the pilot tests could result in revisiting the selected remedy for the source area.

- Reported relatively high sulfate concentrations in site ground water may accelerate electron donor consumption and may become a limiting factor for successful reductive dechlorination. Furthermore, in the absence of sufficient alkalinity, the pH may decrease, inhibiting bacterial growth, and limiting reductive dechlorination.

- Significantly fewer injection points may be required for establishing the biobarriers for the shallow plume periphery and deep plume if preferential injection into thin but highly permeable zones occurs.

- Some of the direct-push ground water samples that have helped define the deep plume may be the result of contamination that was brought down to deeper intervals during sampling rather than contamination that has migrated under natural conditions. As a result, the vertical and horizontal extent of the deep plume may have been overestimated. Installation and sampling of deep monitoring wells can help determine if the plume is accurately delineated.

Based on the above findings, the IDR team presents a discussion on remedial strategy and remedy implementation. The discussion highlights the following items.

- The results from the pre-design investigation and pilot studies could have substantial affect on the remedy design and could warrant revisiting the selected remedy for the source zone. The IDR team suggests reviewing the data from these studies and revisiting the remedy selection process before proceeding with design of the selected remedy. The IDR team can assist with reviewing the data and provide a valuable third-party, technical perspective.

- Injection of oxidants or nutrients for the shallow plume core and hot spot remedy might be efficiently accomplished through trenches or horizontal wells. In addition, the amount of oxidant or nutrient that might be needed is likely less than estimated in the Feasibility Study due to preferential flow through the thin sand lenses. The estimated costs for injections (both materials and labor) may be higher than needed. Depending on the outcome of the pilot studies, ERD rather than ISCO with ERD polishing, may be more appropriate for remediating this zone.

- The preferred flow of water, contamination, and injected nutrients through the thin sand lenses could substantially reduce the estimated amount of nutrients and the number of injection points for implementing ERD in the shallow plume periphery and deep plume. This could affect remedy cost, but it can also affect remedy performance. The injection of too much donor can also result excessive organic acids that could lower the pH and inhibit ERD.

- The IDR team believes that the remediation time estimates presented in the ROD appear optimistic for a heterogeneous subsurface with clays and may bias remedial decisions. PCE and its degradation products have diffused into clay material for nearly 40 years. Based on experience at other sites, the IDR team believes that contamination that has diffused into the clay will continue to contribute dissolved contamination to the more transmissive zones for decades. The IDR team suggests that the site team adjust its expectations for the remedy time frame to avoid the potential for moving away from an ERD biobarrier remedy that is working.

- The cost for the ERD biobarrier remedy will be highly dependent on how long the biobarrier lasts between injections. The site team has estimated that injections will be needed every 15 months. The pilot study results will help determine if this frequency is appropriate.

- The cost for the ERD biobarrier remedy will also be highly dependent on the true extent of the deep plume. Results from the pre-design investigation will help define the true extent of the deep plume and volume that requires remediation.

In addition to the above strategy-related recommendations, the IDR team provides the following items for consideration with respect to implementation.

- Given the heterogeneous nature of the site and the importance of stratigraphy for interpreting the site conceptual model, use rotosonic drilling during pre-design activities to obtain better cores for analysis.

- When planning for the ERD injections, consider the use of extracted ground water, rather than potable water.

- The IDR team provides specific suggestions for monitoring well locations and depth intervals. Suggestions are also provided to conduct pumping tests in specific wells.

- The IDR team suggests that data validation be limited during the long-term monitoring program given that data collected during the Remedial Investigation, data collected during pre-design activities, and a long record of long-term monitoring data will be available to help determine the validity of individual samples.

PREFACE

This report was prepared as part of a pilot project conducted by the United States Environmental Protection Agency Office of Superfund Remediation and Technology Innovation (U.S. EPA OSRTI). The objective of this pilot project is to conduct independent, third-party reviews of soil and ground water remedies that are jointly funded by EPA and the associated State agency. The reviews are ideally conducted during the pre-design, design, or re-design stage so that independent perspectives on the remedy are provided before costs are incurred for implementing and operating the remedies. The project contacts are as follows:

Organization	Key Contact	Contact Information
U.S. EPA Office of Superfund Remediation and Technology Innovation (OSRTI)	Kathy Yager	USEPA Region 1 - New England Regional Laboratory 11 Technology Drive Mail Code: ECA North Chelmsford, MA 01863-2431 phone: 617-918-8362 yager.kathleen@epa.gov
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1.0 INTRODUCTION

1.1 PURPOSE

During fiscal years 2000 and 2001 independent reviews called Remediation System Evaluations (RSEs) were conducted at 20 operating Fund-lead pump and treat (P&T) sites (i.e., those sites with pump and treat systems funded and managed by Superfund and the States). Due to the opportunities for system optimization that arose from those RSEs, EPA OSRTI has incorporated RSEs into a larger post-construction complete strategy for Fund-lead remedies as documented in *OSWER Directive No. 9283.1-25, Action Plan for Ground Water Remedy Optimization*. OSRTI has since commissioned RSEs at additional Fund-lead sites with P&T systems.

Lessons learned from the RSEs conducted to date indicated potential value in conducting independent reviews during the pre-design, design, or re-design stage of a remedy so that an independent perspective from a peer review can be considered before a remedy is implemented and operated. As a result, the EPA OSRTI Technology Innovation and Field Services Division is conducting pilot Independent Design Reviews (IDRs) at Fund-lead sites that are nominated by the EPA Regions. These sites are typically at one of the following stages:

- Pre-design – The Region is in the process of determining the remedy for the site. The Remedial Investigation is typically completed and the site team is evaluating the feasibility of several remedial options.

- Design Stage – The Region has selected a remedy and documented it in a Record of Decision (ROD). The Region is at any phase of the Remedial Design stage.

- Re-Design Stage – The Region has selected, designed, and may have implemented a remedy but the remedy is being reconsidered. Based on data collected to date, the Region is considering new remedial options or is designing a new remedy for the site.

An Independent Design Review (IDR) involves a team of expert hydrogeologists and engineers that are independent of the site, conducting a third-party peer review of remedy selection, remedy design, or remedy re-design. The site team is chosen based on their ability to conduct and document a thorough evaluation and their experience with the type of contaminants, hydrogeology, and remedial technology at the subject site. It is a broad review that considers the goals of the remedy, site conceptual model, available site data, performance considerations, protectiveness, cost-effectiveness, and closure strategy. The review includes reading site documents, visiting the site for one day, discussing the site with the site team, and compiling a report that includes findings and a discussion regarding remedial options and/or items for consideration during design. Consideration is given to stakeholder input to the degree that input is provided in site documents or during interviews with the site team, but because the review is technical in nature, no separate meetings are held with each stakeholder. The purpose of the review is to gain a thorough understanding of the site conceptual model and drivers for the site and to provide findings and analysis that are of value to the site team in making decisions regarding remedy selection and design. The findings and analysis presented in the IDR report are based on the information provided and the discussions with the site team and could change if additional information were made available. Because of the limited scope of the IDR process, the information used in the analysis is assumed to be accurate unless errors in the information are discovered during the IDR. The IDR is intended to be a constructive process and is not intended to criticize past actions or to simply document site details.

The findings are the opinions of the IDR team and the discussion is intended to help the site team identify opportunities for improvements. In many cases, further analysis, beyond that provided in the IDR report, may be needed prior to implementing items presented in the discussion. The considerations provided in the IDR report are the opinions of the IDR team and do not constitute requirements for future action, but rather are provided for the consideration by the Region and other site stakeholders.

The Grants Chlorinated Solvents Plume Superfund Site in Grants, Cibola County, New Mexico was selected by EPA OSRTI based on a nomination from EPA Region 6. The remedy is in the early design stage and has an estimated cost of $29.5 million. This report provides a brief background on the site, a summary of observations made during a site visit, and recommendations regarding the design of the selected remedy. The cost impacts of the recommendations are also discussed.

1.2 TEAM COMPOSITION

The team IDR team consists of the following individuals:

Name	Affiliation	Phone	Email
Kirby Biggs	U.S. EPA OSRTI	703-299-3438	Biggs.kirby@epa.gov
Mike Kovacich	GeoTrans, Inc.	734-213-2204	mkovacich@geotransinc.com
Peter Rich	GeoTrans, Inc.	410-990-4607	prich@geotransinc.com
Doug Sutton	GeoTrans, Inc.	732-409-0344	dsutton@geotransinc.com
Kathy Yager* (not present)	U.S. EPA OSRTI	617-918-8362	Yager.kathleen@epa.gov

** Project coordinator(s)*

1.3 DOCUMENTS REVIEWED

The following documents were reviewed during the IDR process. The reader is directed to these documents for additional site information that is not provided in this IDR report.

Author	Date	Title
CH2M Hill	12/2005	Final Remedial Investigation Report
CH2M Hill	3/2006	Final Feasibility Study Report
U.S. EPA	6/30/2006	Record of Decision
CH2M Hill	3/26/2007	Remedial Design Status Memorandum
U.S. EPA	3/2007	Remedial Design Fact Sheet
U.S. EPA	7/31/2007	Analytical Data

1.4 PERSONS CONTACTED

The following individuals associated with the site were present for the visit:

Name	Affiliation	Phone	Email
Sai Appaji	U.S. EPA Region 6 (RPM)	214-665-3126	appaji.sai@epa.gov
Jeff Minchak	CH2M Hill		
Joe Sterling	CH2M Hill		
Paul Favara	CH2M Hill		
Mike Perlmutter	CH2M Hill		

1.5 BASIC SITE INFORMATION AND SCOPE OF IDR

The Grants Chlorinated Solvent Plume (GCSP) site is defined by an area of ground water that contains chlorinated solvents. The chlorinated solvents in ground water are primarily a result of releases from dry cleaning operations. Chlorinated solvents detected in ground water at the site include tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), 1,1-dichloroethene (1,1-DCE), and vinyl chloride (VC). The site is located in a primarily mixed commercial/residential area and encompasses approximately 12.25 acres. Several possible sources for the release of chlorinated solvents to the ground water were identified during the Preliminary Assessment (PA) and Site Inspection (SI) (NMED, 2001), and the RI (EPA, 2005a), most of which are dry cleaning facilities or former dry cleaning facilities. Two primary areas are targeted as source areas by the Record of Decision (ROD). The primary source area is the Holiday Cleaners facility at the corner of First Street and Monroe Avenue, and a secondary source area is the abandoned dry cleaning facility at First Street and Washington Avenue. EPA will address the site as one operable unit divided into five categories: indoor air, source areas, shallow plume core and hot spot, shallow ground water plume periphery, and the deeper ground water plume. The ROD specifying remedies for these five categories was signed on June 30, 2006, and at the time of the IDR site visit the site team was starting the remedial design and implementing pre-design investigation and pilot studies. This IDR considers all five categories, but most of the focus is placed on the soil and ground water remedy given that the indoor air remedy is underway. Results from pre-design activities conducted after the IDR site visit are not included in this report and are reserved for future discussion between the IDR team and the site team.

The IDR report provides discussion on remedial strategy and implementation for the site team to consider during the design process of the soil and ground water remedy. Although contaminants associated with petroleum hydrocarbons are also present in the area, they are related to other sources, are not primary drivers for the GCSP site, and are not a focus of this IDR.

Attachment A of this report includes ten figures from the 2005 Final Remedial Investigation that illustrate the following:

- Lithologic cross-section
- Soil data
- Ground water plume map
- Cross-section locations
- Longitudinal cross section of geology
- Longitudinal cross section of contaminant distribution
- Structures with vapor mitigation systems
- The extent of the source areas
- Conceptual layout of the in-situ oxidation portion of the shallow plume core remedy
- Conceptual layout of the enhanced reductive dechlorination portion of the shallow plume core remedy

- Conceptual layout of the remedy for the shallow ground water plume periphery
- Conceptual layout of the remedy for the deep ground water plume

2.0 SITE BACKGROUND AND CONCEPTUAL MODEL

The following description reflects the site conceptual model based on data collected during the Remedial Investigation and early Remedial Design. Additional interpretation and commentary is provided by the IDR team where noted. The discussion is limited to the aspects of the site and site conceptual model that are relevant to the scope of the IDR.

2.1 SITE LOCATION AND HISTORY

The site location and setting is discussed in Section 1.5 of this report. A brief summary of the site history, including enforcement activities, is as follows:

- Several site investigations have been performed during various phases by the New Mexico Environmental Department (NMED), CH2M HILL (contractor to EPA), and the U.S. Geological Survey (USGS). Chlorinated solvents were first identified by NMED in 1993 during an investigation at a local gasoline station. Prior to 2004, NMED completed several investigations related to the local gasoline station and to the initial discovery of chlorinated solvents. The activities included soil and ground water sampling from up to 23 direct-push borings, sampling existing monitoring and inactive domestic wells, installing and sampling six additional wells, conducting a passive soil vapor survey, sampling water from the sediment pore space of the Rio San Jose Channel.

- The site contractor conducted four rounds of indoor, outdoor, and background air sampling to evaluate vapor intrusion into buildings in the vicinity of the site. A total of 16 structures were evaluated.

- Two soil vapor sampling events were conducted to evaluate soil vapor concentrations in the vicinity of buildings potentially affected by vapor intrusion. A total of 35 soil vapor samples were collected for analysis.

- The site contractor completed a two phased direct push remedial investigation in February and May of 2004. A total of 34 potential source area direct push borings were completed to collect 102 soil samples including eight duplicates. A total of 81 direct push soil borings were used to define the lateral extent of chlorinated solvent contamination in groundwater and four direct push soil borings were used to determine the vertical extent. Most of the direct push investigation was limited to the upper 16 feet of alluvium.

- Two rounds of ground water sampling of 28 existing monitoring wells and three abandoned domestic wells were conducted. One was conducted by the site contractor in 2004 and the other was conducted by the USGS in 2005. One round of water level measurements was conducted to determine ground water flow pattern.

- Slug tests were performed and analyzed by the USGS at 24 of the existing monitoring wells in the site vicinity in 2005.

2.2 SITE HYDROGEOLOGY

A total of 85 shallow borings and four deeper borings were drilled and lithologically characterized during the investigation activities. The lithology in all of these borings was dominated by clay and silt with thin layers of sand or silty sand present at varying depths. A 6-inch to 1-ft thick sand and silty sand layer was identified continuously from the Holiday Cleaners to at least the intersection of Washington Avenue and Anderman Street (over 1,200 feet away) at a depth gradually increasing from approximately 8 ft below ground surface (bgs) to approximately 16 ft bgs.

Lithologic information was also collected at deeper intervals but to a maximum of 50 feet bgs. Figure 3-2 from the Remedial Investigation (see Attachment A), illustrates the shallow send lens described above, the presence of other sand lenses to a depth of 40 feet bgs, and the absence of lithologic information below 40 feet.

The water table is located approximately 6 to 8 feet bgs although water is present discontinuously at shallower intervals. From 6 feet bgs to 40 feet bgs, ground water is present in relatively thin sand and silt lenses within competent clay. Over a five-year period of monitoring at the site, ground water flow directions have remained consistent. In the main portion of the site, and along the centerline of the plume, flow is to the southeast with a hydraulic gradient of approximately 0.002 to 0.003. The vertical gradient has only been determined at one location (GMW-1), and has consistently been upward.

The hydraulic conductivity as determined by the slug tests conducted and analyzed by the USGS ranges from below 5 feet per day at many locations to as high as 90 feet per day at one location. A hydraulic conductivity of 30 feet per day was measured at one location, and a hydraulic conductivity of 20 feet per day was measured at two locations. Based on this information and an assumed effective porosity of 0.28, the ground water velocity in the vicinity of the main plume ranges from approximately 10 to 350 feet per year.

Based on drilling conducted at the site since the Remedial Investigation, a second sand lens, approximately 20 feet thick appears to be present below the clay from about 40 feet to 60 feet bgs. Below 60 feet bgs, competent clay is reported.

2.3 EXTENT OF CONTAMINATION

There are two known sources of PCE at the site: the active Holiday Cleaners at the corner of First Street and Monroe Avenue and the abandoned dry cleaning facility on First Street north of Washington Avenue. Based on interviews during the investigation and assessment phases, the release mechanisms at the Holiday Cleaners site were routine spills, overflows from an above ground tank at the rear of the building, releases from a system of interior drains and disposal of impacted decant water in the sanitary sewer. The Holiday Cleaners facility began operation in 1969. Although the facility continues to operate, the equipment has reportedly been updated. Release mechanisms at the abandoned facility are unknown.

2.3.1 SOIL

The soil investigations conducted to date have primarily been aimed at determining the sources of the ground water contamination. Figure 5-2 from the Remedial Investigation shows the results of soil sampling results. Extensive characterization of the unsaturated soils in the source areas was not conducted prior to the IDR site visit and is planned as part of future activities.

2.3.2 GROUND WATER

Figures 5-3 and 5-12 from the Remedial Investigation illustrate the horizontal and vertical extent of chlorinated solvent contamination in ground water. The location and orientation of the cross-section in Figure 5-12 is illustrated on Figure 3-1 of the Remedial Investigation. The main portion of the plume extends southeast of Holiday Cleaners. The highest detected PCE concentration in ground water (51,000 ug/L) during the Remedial Investigation is from a direct-push ground water sample collected approximately 250 feet downgradient of Holiday Cleaners. In addition, PCE concentrations from direct-push activities are as high as 9,900 ug/L approximately 700 feet downgradient of Holiday Cleaners and 1,900 ug/L approximately 1,200 feet downgradient of Holiday Cleaners. The above-mentioned concentrations are present in the 0.5 to 1 foot thick sand lens that is approximately 8 to 16 feet bgs. Contamination above the Maximum Contaminant Level (MCL) extends further downgradient and also extends as deep as 80 feet bgs but at generally much lower concentrations.

Contamination extending downgradient from the abandoned cleaners is generally much lower in magnitude and extent than that downgradient from Holiday Cleaners.

Indoor air sampling indicated that one or more chlorinated solvents exceeded Tier 3 levels and required active mitigation at three structures and exceeded Tier 2 levels and required additional evaluation at eight additional structures.

Sampling of the ground water underlying the Rio San Jose Channel showed no detections of site contaminants of concern.

2.4 RECEPTORS

An ecological risk assessment was not conducted for the site because the site team concluded that the contaminants of concern would not persist in surface soils or surface waters. Therefore, the primary risks considered by the site team are associated with human health. The Baseline Human Health Risk Assessment for the site presents the following conclusions:

- Water from the shallow aquifer is not currently being used in the household due to the presence of a public water supply; however, this water does contain chemicals at concentrations above their MCLs. Additionally, property owners are not legally prohibited by the City of Grants from using ground water.

- Water from the shallow aquifer has the potential to affect both the indoor air and the drinking water in the area.

- Residential indoor air contaminants of potential concern (COPCs) for the site are benzene, PCE, and TCE.

- Ground-water COPCs for the site are benzene, bromoform, cis-1,2-DCE, ethylbenzene, PCE, toluene, trans-1,2-DCE, TCE, VC, and total xylenes.

As noted previously, the selected remedy and the IDR focus on the contamination caused by chlorinated solvents. With respect to drinking water, five municipal wells are located within a 4-mile radius of the site, and another well is proposed within 1 mile of the site. Two of the municipal wells are owned by the City of Grants, one is owned by the Village of Milan, and two are owned by the Town of San Rafael. The proposed well would be owned by the City of Grants. All of these municipal water wells are screened (or will be screened) in the San Andres/Glorieta aquifer. Based on a description of regional geology, the top of this drinking water aquifer is approximately 100 to 140 feet bgs. Ground water contamination has been detected at approximately 80 feet bgs.

2.5 REMEDY OBJECTIVES

ROD Remedial Action Objectives

The ROD-specified Remedial Action Objectives (RAOs) for groundwater are as follows:

- Protection from exposure to constituents above MCLs or ARARs
- Restoring groundwater such that constituents are below MCLs or ARARs
- Preventing DNAPL from causing concentrations to exceed MCLs or ARARs
- Reducing concentrations to mitigate vapor intrusion

The ROD-specified RAOs for soil are as follows:

- Prevent groundwater from being impacted above MCLs by contaminant transport from the unsaturated zone
- Protect human health from exposure to constituents in soil
- Reduce concentrations to mitigate vapor intrusion

The RAO for vapor intrusion at the site is to prevent vapor intrusion resulting in exposure in excess of a 10^{-5} elevated cancer risk.

It is noted that the MCLs for PCE, TCE, cis-1,2-DCE, and VC are as follows:

- PCE – 5 ug/L
- TCE – 5 ug/L
- cis-1,2-DCE – 70 ug/L
- VC – 2 ug/L

2.6 DESCRIPTIONS OF THE SELECTED REMEDIES

The June 2006 ROD specifies the following remedies for the soil and ground water contamination.

- Vapor intrusion mitigation systems installed at 14 residences with either indoor air levels resulting in more than a 10^{-5} increased risk for cancer or located over underlying ground water with TCE or PCE concentrations higher than 1,000 ug/l.
- Thermal treatment (presumably electrical resistive heating) with soil vapor extraction of a 150 foot by 100 foot by 80 foot deep volume at Holiday Cleaners and 30 foot by 80 foot by 35 foot deep volume at the abandoned dry cleaners. Heating and extraction is assumed to take place over

a 12 month period. The site team suggests that the need for polishing with another remedy may be needed to meet cleanup standards. Horizontal wells may be added to enhance extraction.

- In-situ chemical oxidation (ISCO) with enhanced reductive dechlorination polishing in the shallow plume core and hot spot. This includes about 221 ISCO injection points. The targeted volume is 800 feet by 150 feet by 20 feet deep with injection targeted between 8 and 20 feet bgs. Enhanced reductive dechlorination is planned as a polishing step for the ISCO.
- Enhanced reductive dechlorination (ERD) barriers in the shallow plume periphery and deep plume including 100 shallow injection wells and 50 deep injection wells. Recent drilling and injection tests in the pilot test areas indicate that a permeable zone may be consistently present at about 40 feet to 60 feet bgs. The treatment planned for this zone is ERD.

Figures 11 through 16 from the ROD illustrate the conceptual areas of implementation for these remedies, and **Figure 1** of this report illustrates a vertical cross-section of the target volume for the ground water remedies.

The site team is in the process of conducting field work to collect data necessary for beginning the design of these selected treatment alternatives. The following is a description of that field work

Pilot Tests

The site team is currently running pilot tests for ISCO and ERD. The ISCO pilot test includes injection of potassium permanganate in a well screened from 8 feet to 20 feet bgs in the shallow plume core. The ERD test includes injection of a lactate and emulsified soybean oil product provided by EOS Remediation, Inc. (EOS) at three locations, each with five depth intervals between 10 and 60 feet bgs. The pilot tests are ongoing through June 2008, with data expected to be available in August 2008.

Source Investigation

Further investigation is proposed on the Holiday Cleaners site in late January 2008 to determine the mass to be remediated in the source zones (dry cleaner properties) and the depth of impacts. The investigation will include drilling boreholes up to an anticipated depth of about 80 feet. Groundwater samples will be taken at intervals and wells will be installed for long-term monitoring. A deep (200 feet bgs) upgradient well will be installed to demonstrate that impacts are not migrating towards deep high production water supply wells.

Additional Monitoring Well Installation

As mentioned above, most of the site characterization was based on shallow direct push data. There is no monitoring well network to indicate plume movement, concentration trends and remedy effectiveness. The site team plans to install about 36 monitoring wells and recognizes the need for several deep wells.

A preliminary design that incorporates information from the above activities is expected in the Fall/Winter of 2008.

The total estimated cost for implementing the remedy is summarized in Table 19 of the ROD. The following table provides a summary of the approximate cost breakdown for the various remedy components.

Remedy Component	Estimated Cost from the ROD
Vapor intrusion mitigation systems	$382,000
Thermal treatment of the source area	$8,018,000
ISCO and ERD polishing of the shallow plume core and hot spot	$6,731,000
ERD barriers in the shallow plume periphery	$3,273,000
ERD barriers in the deep plume	$7,222,000
Subtotal	**$25,626,000**
Additional components (additional investigation, monitoring, project management, Five-Year Reviews, etc.)	$3,582,000
Total	**$29,208,000**

3.0 IDR FINDINGS

The IDR team reports the following findings from the document review, site, and information summarized in the previous section that are pertinent to the remedial strategy and implementation discussion in the following sections of this report. These findings include opinions and interpretations made by the IDR team based on review of the data, experience, and professional judgment and are offered for consideration to the site team. These opinions may differ from those of other potential reviewers and do not necessarily reflect the opinions of U.S. EPA OSRTI, which commissioned this review.

It is noted that EPA and the site contractor plan to conduct additional investigation and are in the midst of conducting pilot studies of the various remedial options and that the findings/interpretations presented below by the IDR team are subject to change based on the results of this additional work.

3.1 FINDINGS RELATED TO SITE HISTORY AND SITE CONCEPTUAL MODEL

The IDR team notes the following findings and interpretations regarding the site conceptual model.

- Ground water is present beneath the site in thin (approximately 1 foot thick) sand and silt lenses within competent clay. The relatively high hydraulic conductivity of these lenses allows for substantial horizontal contaminant transport, which explains how concentrations as high as 1,900 ug/L are present approximately 1,200 feet from the source area despite the abundance of clay in the subsurface.

- A relatively long, continuous lens with a thickness of approximately 1 foot is present approximately 8 feet to 16 feet bgs. Water quality data suggest that the highest concentrations and most significant horizontal transport of site-related contamination occur within this lens.

- Based on water quality data, it appears that a large percentage of the contaminant mass at the site is present in the shallow, continuous lens at 8 feet to 16 feet bgs. A large percentage of the remaining mass may be present in other, deeper lenses.

- A ground water concentration of PCE as high as 3,400 ug/L was detected as deep as 60 feet during direct-push sampling. Limited data at the site suggest an upward hydraulic gradient, which means that dense non-aqueous phase liquid (DNAPL) was likely present as free product at one point to allow for substantial vertical contaminant migration. The presence of additional sand and silt lenses allow for horizontal contaminant migration at deeper intervals. It is also noted, however, that at other locations (e.g., GC-6) the IDR team believes that deep contamination may be the result of bringing down contamination during direct-push sampling rather than natural migration of contamination to this depth. Installation and sampling of monitoring wells at this depth will help confirm or deny if contamination that requires remediation is present as deep as suggested by direct-push samples at GC-6.

- The abundance of silt and clay in the subsurface, the presumed vertical migration of contamination through these low permeability materials, and the age of the plume (perhaps dating back to the 1970s), suggests to the IDR team that aquifer restoration could be diffusion limited given that advective processes are limited in low permeability materials. That is, the IDR team is concerned that contamination significant enough to result in continued concentrations above MCLs is likely present in low permeability materials (particularly near and immediately downgradient of the source area) that will be difficult to reach with most remedial technologies. As a result, although significant contaminant removal in the high permeability units may occur within a reasonable time frame, continued contributions of contamination diffusing from the low permeability materials could occur, potentially delaying the progress toward aquifer restoration.

- The highest ground water detected concentrations of site-related contaminants appear to be downgradient of the source area in the shallow lens and perhaps in deeper lenses. This suggests to the IDR team that the majority of contamination may have already migrated from the source area. This migration may have occurred as dissolved contamination or as free product as evidenced by PCE concentrations as high as 51,000 ug/L approximately 200 feet downgradient of the source area downgradient boundary. The contamination at depth also appears to be downgradient of the source area. The highest detected concentration of 3,400 ug/L at 60 feet bgs is 60 feet downgradient of the source area downgradient boundary. Ground water samples from a direct-push boring within the source area (GC-11) range from less than 5 ug/L to 62 ug/L between 48 and 58 feet bgs.

- GC-11 is the only point within the source area that provides water quality data below 20 feet bgs, and lithologic data is only available to approximately 40 feet bgs. This one location of vertical profiling within the source provides limited data to characterize the vertical extent of contamination and the magnitude of contamination at depth.

- There is a hot spot of the groundwater plume in an area unrelated to the two known sources along Jefferson Avenue. One potential hypothesis is that this hot-spot is due to contaminant migration in the bedding of the sanitary sewer line.

- Concentrations of PCE degradation products (TCE up to 4,800 ug/L, cis-1,2-DCE up to 1,500 ug/L, and vinyl chloride up to 10 ug/l) are highest (over 10 times higher than elsewhere in the plume) in the area near the Allsup underground storage tank site indicating the hydrocarbons in the subsurface are providing a food source for microbes in the area and promoting reductive dechlorination. However, the IDR team believes that the vinyl chloride concentrations are sufficiently low to suggest that effective reductive dechlorination to ethene may not be occurring and that bioaugmentation (i.e., introducing appropriate microorganisms) may be appropriate to foster effective reductive dechlorination.

3.2 FINDINGS RELATED TO DESIGN AND PRE-DESIGN ACTIVITIES

The IDR team notes the following findings and interpretations regarding the various components of the remedy.

Source Area

- Shallow soil borings suggest that much of the Holiday Cleaners property is not contaminated and that much of the contamination is present between the downgradient corner of the building and downgradient property boundary. Additional contamination is likely present beneath a portion of the building, but the area of shallow soils and ground water that require source treatment are likely substantially smaller than the 100-foot by 150-foot area indicated in the ROD, perhaps less than 50% of this area. A smaller treatment volume would likely substantially reduce the estimated remedial costs for source area treatment, and may change the cost-effectiveness of some remedial options that have a high capital cost component. The IDR team believes that additional, thorough characterization of vadose zone and saturated soils is needed before designing the remedy. The IDR team believes that the results of this characterization may also suggesting revisiting the selected remedy.

- The selection of thermal remediation appears to be influenced by the need to treat vadose zone soils and the difficulty of treating these soils with competing technologies such as ISCO and ERD. Limited excavation for the ISCO and ERD options was assumed during remedy selection, but demolition of the building and excavation of the vadose zone soils does not appear to be an option to the site team given their preference to minimize impact to the Holiday Cleaners business. Depending on the extent of vadose zone contamination beneath the building, the site team may consider the option of demolishing the building, excavating soils, and either relocating the Holiday Cleaners business or constructing a new building.

- Because of contaminant migration and perhaps limited water quality and lithologic information with depth, the zone defined as the source area and targeted for thermal remediation does not appear to coincide with the zone of highest detected contamination and vertical migration. The cross-sectional view of the thermal remediation target zone from the ROD is shown in Figure 1, and the plan view of this target zone is presented in Figure 5-3 of the Remedial Investigation (see Attachment A). The zone that seems more appropriate based on existing data for source zone remediation appears to be on the downgradient portion of the Holiday Cleaners property, First Avenue, and properties downgradient of First Avenue. The IDR team believes that findings from the pre-design investigation will be important for selecting the appropriate zone for source area treatment and help establish the dividing line where source zone remediation ends and shallow plume core remediation begins.

- The site team prefers a source area remedy that allows Holiday Cleaners to continue operating. If the area requiring source area treatment is actually downgradient of the building and parking lot, then this may be feasible. However, if thermal treatment is required beneath and immediately around the property, this may be logistically difficult. In theory, a thermal remedy can be designed and implemented with below ground infrastructure, but it would likely be difficult to keep the business operating during the several weeks of construction. In addition, it may be difficult to keep the business operating even with the limited above-ground foot print of the system, operation, and monitoring over a 12-month period. The parking lot of the business is small and access for customers is already challenging, and other dry cleaners are present in the area to provide customers with an alternative.

- Other options for source area remediation discussed in the ROD and Feasibility study include ISCO with ERD polishing and ERD alone. These two options both included limited excavation (an estimated total of 638 cubic yards), with limited dewatering, and disposal of excavated soil as a hazardous waste. The ISCO included injecting one and a half pore volumes into the target zone, and the ERD polishing or ERD-only remedies including injecting one half of a pore volume into the target zone on many occasions over several years. Due to the hydrogeology of the site, the predominance of silts and clays, and the existence of sand lenses, the assumption of injecting one pore volume or a half-pore volume may be a significant overestimate. The injected oxidants or nutrients would likely preferentially migrate through the sand lenses and bypass the tighter silts and clays that likely occupy the majority of the target zone. Based on a preliminary review of the data presented in Figure 3-2 of the Remedial Investigation, it appears that sand lenses may comprise approximately 25% or less of the aquifer volume near the source area. Because the sand lenses occupy only a fraction of the volume, these remedial options may be significantly overestimating the amount of oxidant or nutrient that would be effective at treating the source zone.

- If the smaller treatment zone (e.g., approximately 50%) discussed in the first finding of this section (i.e., Section 3.2) and the above-noted fraction (e.g., approximately 25%) of the source area aquifer that will likely readily receive oxidants or nutrients are combined, then the pore volume of the source area that would be treated would be approximately 1/8 of the volume assumed in the Feasibility Study. That is, the number of injection points and the masses of oxidants and nutrients to inject may be high by a factor of approximately 8. This could have a significant influence on selecting the remedy, especially given the assumed relatively high injection masses due to the potentially high soil oxidant demand or high sulfate concentrations that could negatively affect the ISCO or ERD remedies, respectively. It is also noted that the use of a horizontal well or injection trench, which is mentioned during the excavation portion of the ISCO/ERD and ERD options, does not seem to be included when calculating the number of injection points. The results and lessons learned from conducting the pilot tests may help better estimate the volumes that require treatment and the amount of oxidant or nutrient that is appropriate. The IDR team believes that the findings from the pilot tests could result in revisiting the selected remedy.

- All options considered for source area treatment consider the likely possibility of additional remediation if the original remedy does not result in achievement of cleanup standards. The site team suggests that thermal remediation will take no longer than 12 months but that additional polishing by either a passive or active remedy may be needed to reach standards. The ISCO with ERD polishing suggests an approximate 5 to 6 year duration given that an five ERD injections will occur at 15-month intervals. The ERD-only approach suggests an approximate 15 year duration given that 12 ERD injections will occur at 15 month intervals.

Shallow Plume Core and Hot Spot

- The selected remedy for the plume core and hot spot includes ISCO with ERD polishing. The assumed treatment depth is from 8 feet to 20 feet, and the injection of oxidants and nutrients is based on the total pore volume for this depth interval. However, the majority of the mass and ground water flow is in a thin sand lens that is approximately 0.5 to 1 foot tick. The oxidants or nutrients will likely preferentially enter this thin lens; therefore, it is likely more appropriate to base the quantities for injection on this thin lens plus a factor of safety rather than on the whole volume. As a result, the injection quantities needed may be an order of magnitude lower than what the site team has calculated if all other parameters and assumptions remain unchanged.

- The ROD states that this portion of the remedy is flexible and that the decision to implement the ISCO portion is dependent on pilot testing results and the presence of DNAPL. The pilot study results and an absence of DNAPL may suggest that implementing an ERD biobarrier approach is more appropriate and cost-effective than ISCO and ERD polishing. Based on the cost breakdowns in the Feasibility Study and information in the ROD, using the biobarrier approach would save approximately $5 million. The ISCO/ERD approach was selected for this zone because it more rapidly removes mass than the competing approaches. The estimated time frame for the ISCO/ERD approach is approximately 5 to 6 years. The site team's estimated time frame for the biobarrier approach for the shallow plume core and shallow plume periphery (i.e., the area downgradient and surrounding the plume core) is approximately 20 years. The IDR team notes that diffusion of contaminant mass out of the lower permeability layers over time (as is assumed by the site team for the source area) may also contribute to extending remedy time frames in the shallow plume core and hot spot such that the remedial time frame might be longer than the 5 to 6 year time frame that is estimated for the ISCO/ERD approach.

- The results and lessons learned from conducting the pilot tests may help better estimate the volumes that require treatment and the amount of oxidant or nutrient that is appropriate. The IDR team believes that the findings from the pilot tests could result in revisiting the selected remedy. In addition, the pre-design investigation will help further refine the volumes requiring treatment.

Shallow Plume Periphery and Deep Plume

- Reported relatively high sulfate concentrations in site ground water may accelerate electron donor consumption and may become a limiting factor for successful reductive dechlorination. If no naturally occurring pH buffering is present, high organic carbon loading during ERD may result in low pH and inhibit bacterial growth. Evaluation of the pilot tests will be critical to the final design.

- Approximately 20,000 gallons of substrate amended water was injected into 10-foot screens in each of the three injection wells in the ERD pilot test area. Assuming 25% effective porosity in a uniform receiving formation this quantity could result in an injection radius of influence of approximately 18.5 feet. However, if most of the substrate amended water was actually injected into a 3 or 1 foot layer within the screen interval, the radius of influence within this layer could be as much as 34 or 58 feet, respectively. Significantly fewer injection points may be required if preferential injection into thin but highly permeable zones occurs.

- The frequency of injections required to maintain the biobarriers and the true extent of the shallow plume periphery and deep plume have an substantial influence on the costs for this portion of the remedy, and both of these parameters are relatively uncertain in the absence of information from the pre-design investigation and the pilot studies.

4.0 DISCUSSION REGARDING REMEDIAL STRATEGY AND IMPLEMENTATION

4.1 CONSIDERATIONS REGARDING STRATEGY

The following discussion pertains to determining and/or refining the remedial strategy for the site based on the pre-design investigations that are planned or underway and other information that becomes available during the design process. The IDR process, like the design process, is dynamic, and the IDR team can be available to continue providing an independent perspective as additional information is collected and the site conceptual model evolves.

4.1.1 CONSIDERATIONS FOR SOURCE AREA REMEDIATION

As discussed in Section 3.2 of this report, the IDR team believes that the pre-design investigation and pilot studies will provide important information that may result in revisiting the selected remedy for the source area. The IDR team offers some potential outcomes of the pre-design investigation that may result in a significant change to design or to an alternative remedial strategy.

- The source area investigation confirms that the contamination in the source zones is limited to significantly smaller portions of the target areas assumed in the ROD and contamination in these zones is shallower than anticipated because the majority of vertical migration occurred downgradient of these zones. These findings could result in an overall smaller volume to treat with the selected source zone remedy. Limited excavation may become the most appropriate option for vadose zone soils, and ISCO or ERD may be more cost-effective for this smaller volume than the thermal remediation.

- The pre-design investigation confirms that the majority of contaminant mass at the site has actually migrated downgradient from the source zone target areas assumed in the ROD. The target zones for source area remediation may therefore change. For example, this could result in source zone treatment occurring under First Avenue and/or the properties on the downgradient side of First Avenue rather than on the Holiday Cleaners property.

- The pre-design investigation may suggest little or no difference in contaminant levels for the source area and shallow plume core, suggesting that the same remedial strategy be implemented for both locations.

- The pilot studies may suggest that remediation of the shallow plume core, shallow plume periphery, and deep plume will be substantially limited by diffusion of contamination from low permeability zones into the more permeable sand lenses. This diffusion-limited scenario could substantially increase the estimates of remedy duration, and the site team may see the benefit of a remedial approach that allows for active remediation to occur over a longer time frame to address the long-term contamination. Additionally, the pilot tests may suggest that remediation of the shallow plume core and plume periphery is impractical with ISCO (perhaps due to a high SOD) or ERD (perhaps due to high sulfate levels). If this is the case, then remediation within 1 year with thermal remediation may not have a significant advantage relative to remediation within 5 to 6 years (or longer) with ISCO and/or ERD, or an indefinite time frame for a source control approach.

- The preferred flow of water, contamination, and injected oxidants/nutrients through the thin sand lenses could substantially reduce the estimate amounts of oxidants/nutrients and the number of injection points. The pilot test results may suggest that these changes could substantially improve the cost-effectiveness of these remedial approaches, making them more appropriate for the source zone.

- Further work on the Holiday Cleaners property and discussions with technology vendors may help the site team confirm that the selected remedy could be applied for a 12-month period without detriment to the Holiday Cleaners business or it could help the site team realize that these activities would be impractical for the business to overcome for logistical reasons. An alternative remedy may be more appropriate to achieve the objective of minimizing effects on the Holiday Cleaners business.

This list of potential outcomes is not intended to be an exhaustive list, and it is not intended to suggest the immediate need to reconsider the selected remedy. This list is provided to demonstrate the IDR team's opinion that the current focus be placed on evaluating the results from the pre-design investigation and pilot studies and then revisiting the remedy selection process to determine if the selected remedy remains the most appropriate remedy for this portion of the site. Adhering to the selected remedy before evaluating the information from these studies could potentially result in proceeding with a less appropriate remedy or a mis-applied remedy. The IDR team can assist with analyzing the data from these studies and providing a valuable third-party perspective.

4.1.2 CONSIDERATIONS FOR SHALLOW PLUME CORE AND HOT-SPOT REMEDIATION

The current selected remedial approach includes ISCO with ERD polishing, but indicates that the selected remedy is flexible depending on pilot study results. If pilot studies show that ISCO will not provide cost-effective contaminant destruction then ERD injections or the use of ERD biobarriers (selected for the plume periphery) may be used instead. For either ISCO or ERD, the sand/silt lenses above 40 feet bgs are within competent clays so that relatively small volumes will be available for treatment. Injection of chemicals could be preferentially done into the lenses possibly using trenches or horizontal wells rather then many vertical injection points. The use of horizontal wells and trenches has its own challenges with respect to evenly injecting mass along a long horizontal length, but also has advantages in terms of improving coverage cost-effectively, particularly at shallow depths. Horizontal wells might also have the added challenge of properly locating/installing the well within a thin lens.

Estimates for the labor needed for injection (ISCO and ERD) appear to be high. Based on experience from the pilot test and from the IDR team's experience at other sites, material could be injected into the subsurface in less than 50% of the time estimated.

Soil Oxidant Demand (SOD) may be higher than assumed during the Feasibility Study but the volume requiring treatment is likely less. An SOD of 5 g/kg was used in the Feasibility Study but a thickness of 80 feet in the source area and about 12 feet in the shallow Plume Core and Hot Spot was used. Actual SOD based on bench testing is about 10 g/kg but ISCO would be concentrated on the thin transmissive lens rather than across the soil column. Actual chemical requirements will likely be less than projected. However, ERD rather than ISCO may still be a more appropriate remedy for this zone to reduce interferences of ISCO and ERD and take advantage of potential economies of scale for using the same remedial approach. Pilot testing will provide key information about remedy selection for this zone.

Results from the pre-design investigation and the pilot studies should be considered to determine/refine the appropriate volume of the aquifer to treat, the amount of oxidant/donor to inject, and the frequency injections.

4.1.3 CONSIDERATIONS FOR SHALLOW PLUME PERIPHERY AND DEEP PLUME REMEDIATION

The preferred flow of water, contamination, and injected nutrients through the thin sand lenses could substantially reduce the estimate amount of nutrients and the number of injection points for ERD. This could affect remedy cost, but it can also affect remedy performance. The results of the pilot tests should be carefully analyzed to determine the appropriate amount of nutrients to inject during each event and the appropriate interval between events. The injection of too much donor can result excessive organic acids that could lower the pH and inhibit reductive dechlorination.

Installation and sampling of shallow and deep monitoring wells during the pre-design investigation should help confirm the plume delineation suggested by direct-push sampling. Because direct-push sampling through high levels of shallow contamination could result in introducing contamination at deeper intervals, the plume defined by direct-push sampling may not be accurate, and the target volume for remediation may be smaller and the cost lower.

Another factor that contributes substantially to the cost of a long-term biobarrier remedy is the frequency that injections are required. The industry standard and the frequency suggested by the site team is approximately one injection every 15 months. The pilot test results should be carefully reviewed to determine if this frequency is appropriate for this site. The relatively high velocities within the sand lenses could lead to more rapid consumption of the donor and the need for more frequent injections.

4.1.4 RECONSIDER EXPECTATIONS FOR REMEDY TIME FRAMES AND PROGRESS TOWARD RESTORATION

The IDR team believes that the remediation time estimates presented in the ROD appear optimistic for a heterogeneous subsurface with clays and may bias remedial decisions. PCE and its degradation products have diffused into clay material for nearly 40 years. Based on experience at other sites, the IDR team believes that contamination that has diffused into the clay will continue to contribute dissolved contamination to the more transmissive zones for decades. Achieving MCLs for the entire plume may not be feasible with any technology or reasonable cost in less than several decades. The success of the injection-based remedies that have been proposed for the majority of the site area are based on the ability of the reagents to reach contamination. The IDR team believes that diffusion will be the primary mechanism for transport of reagents into the impacted clay or contaminant transport out of the impacted clay. Given that diffusion has been occurring for decades, it is reasonable to assume that at least the same amount of time or longer will be required for remediation.

The IDR team believes appropriate expectations for remedy time frames are important so that the site team does not abandon a remedy that is working and switch from remedy to remedy when the site conditions are the limiting factor that will also affect other remedy alternatives.

4.2 CONSIDERATIONS PERTAINING TO IMPLEMENTATION

4.2.1 CONSIDER ROTOSONIC DRILLING DURING PRE-DESIGN DRILLING

The complex interbedded nature of the site geology suggests that greater understanding of the vertical and horizontal distribution of the more permeable lenses and layers is needed. As indicated during the IDR meeting, the IDR team strongly encourages the use of rotosonic drilling techniques at key locations at the site. The quality of the soil profiles generated from this drilling technique should help facilitate a greater understanding of the local geology that could aid in completing the final remedial designs. As mentioned above, the relatively thin high transmissive zones have can play a large role in contaminant transport, the amount of reagent needed for remediation, and the level of effort for injection.

4.2.2 USE GROUNDWATER INSTEAD OF POTABLE WATER DURING REMEDIATION INJECTIONS

Municipal water from the City of Grants was used as the make-up water for the recently completed pilot tests. Substantially more water will be needed for full scale ERD. Recent drilling and injection work in the ISCO and ERD pilot test areas suggested that transmissive units are present at the site. Consideration should be given to whether one or two of the more permeable units could yield enough water to serve as temporary extraction wells. These wells could be used to provide an alternative water source. Site groundwater would be a preferred alternative to municipal water for use as make-up water for three principle reasons:

- Site water will be better suited geochemically. For example, it will already be reduced.
- Strategically placed extraction and injection wells could help sweep donor amendments or oxidizers into areas where access for injection is limited (e.g., under a commercial or residential building).
- Use of site water will prevent the introduction of substantial quantities of municipal water into the targeted injection zones and lower the chance of pushing contaminated water into other less impacted areas.

4.2.3 OTHER RECOMMENDED SITE CHARACTERIZATION DETAILS

The IDR team agrees with the site team that multiple new monitoring wells are needed in multiple vertical zones. **Figure 2** proposes locations where the IDR team recommends installation of wells and the proposed screened intervals for those wells. The monitoring well locations are intended to provide an improved understanding of contaminant distribution and the site stratigraphy given that the thin transmissive zones can have a significant effect on remedial design considerations. The IDR team suggests that aquifer pumping tests be performed at PM-2S/D, PMW-4S/D and PMW-6S/D to better determine the site hydraulic conditions and to determine whether site water could be used as an alternative to municipal water.

Consistent with Section 4.2.1, some of this drilling could be conducted with rotosonic drilling because this drilling technique provides better quality cores than direct-push technologies and will help the site team better understand the variable stratigraphy at this site. The IDR team proposes that the 10 monitoring well locations (shallow and deep well pairs) presented on **Figure 2,** be completed using rotosonic methods. Although this drilling technique has historically been much more expensive than hollow stem auger and other traditional drilling methods, the costs for this technology are now much more comparable to other technologies in many parts of the country.

4.2.4 LIMIT DATA VALIDATION DURING LONG-TERM SITE MONITORING

Data validation can play an important role during investigation and site closure activities, but is often redundant during long-term monitoring given the repetitive nature of the sampling, the long-term nature of the monitoring, and an established record of concentrations and concentration trends. As a result, the IDR team recommends that the site team consider limiting data validation to a small percentage of the data once a long-term site monitoring program begins.

5.0 SUMMARY

The IDR process included a detailed review of the site documents, a site visit, interviews with the site team, and analysis of the information collected. Based on this information and analysis, the IDR team presents the following findings. These findings include opinions and interpretations made by the IDR team based on review of the data, experience, and professional judgment and are offered for consideration to the site team. These opinions may differ from those of other potential reviewers and do not necessarily reflect the opinions of U.S. EPA OSRTI, which commissioned this review.

- Ground water is present beneath the site in thin (approximately 1 foot thick) sand and silt lenses within competent clay. A relatively long, continuous lens with a thickness of approximately 1 foot is present approximately 8 feet to 16 feet bgs. Water quality data suggest that the highest concentrations and most significant horizontal transport of site-related contamination occur within this lens.

- A ground water concentration of tetrachloroethene (PCE) as high as 3,400 ug/L was detected as deep as 60 feet during direct-push sampling. Limited data at the site suggest an upward hydraulic gradient, which means that dense non-aqueous phase liquid (DNAPL) was likely present as free product at one point to allow for substantial vertical contaminant migration.

- The abundance of silt and clay in the subsurface, the presumed vertical migration of contamination through these low permeability materials, and the age of the plume (perhaps dating back to the 1970s), suggests to the IDR team that aquifer restoration could be diffusion limited, resulting in a longer than expected time frame for remediation.

- Ground water data suggest to the IDR team that the majority of contamination may have already migrated from the source area.

- Lithologic and water quality data with depth is limited.

- Concentrations of trichloroethene and cis-1,2-dichloroethene (PCE degradation products) are 10 times higher near the Allsup underground storage tank site than elsewhere in the plume indicating the hydrocarbons in the subsurface are providing a food source for microbes in the area and promoting reductive dechlorination. However, concentrations of vinyl chloride are not as high, suggesting that reductive dechlorination is not complete and that bioaugmentation (i.e., introducing appropriate microorganisms) may be appropriate.

- Limited soil data to date indicate that the area and volume for source remediation is likely much smaller than indicated in the Record of Decision (ROD), and the smaller volume for remediation may change the cost-effectiveness of some remedial options that have a high capital cost component.

- Because of contaminant migration and perhaps limited water quality and lithologic information with depth, the zone defined as the source area and targeted for thermal remediation does not appear to coincide with the zone of highest detected contamination and vertical migration. The zone that seems more appropriate based on existing data for source zone remediation appears to be on the downgradiet portion of the Holiday Cleaners property, First Avenue, and properties downgradient of First Avenue.

- The site team prefers a source area remedy that allows Holiday Cleaners to continue operating. If the area requiring source area treatment is actually downgradient of the building and parking lot, then this may be feasible. However, if thermal treatment is required beneath and immediately around the property, this may be logistically difficult both during construction and operation due to the small property and the limited access to customers.

- Other options for source area remediation discussed in the ROD and Feasibility Study include limited excavation followed by in-situ chemical oxidation (ISCO) with enhanced reductive dechlorination (ERD) polishing or ERD alone. Injections of oxidants or nutrients will preferentially enter the sand lenses, which occupy only a percentage of the aquifer volume within the source area. As a result, the amount of oxidant and nutrient required may have been significantly overestimated by using the entire volume of the source area.

- Based on the finding that only a portion of the Holiday Cleaners site is contaminated and the role of the sand lenses in controlling oxidant/nutrient delivery, the IDR team believes that the effective volume of the <u>source area</u> that would be treated by ISCO or ERD would be almost an order of magnitude smaller than the volume assumed in the Feasibility Study. Based on available data, the amount to be injected and the number of injection points may therefore be high by almost an order of magnitude if all other factors remain unchanged.

- The assumed treatment depth for the <u>shallow plume core and hot spot</u> is from 8 feet to 20 feet, and the injection of oxidants and nutrients is based on the total pore volume for this depth interval. However, the majority of the mass and ground water flow appears to be in a thin sand lens that is approximately 0.5 to 1 foot tick. As a result, the injection quantities needed may be an order of magnitude lower than what the site team has calculated if all other parameters and assumptions remain unchanged.

- The IDR team notes that diffusion of contaminant mass out of the lower permeability layers over time (as is assumed by the site team for the source area) may also contribute to extending remedy time frames in the <u>shallow plume core and hot spot</u> such that the remedial time frame might be longer than the 5 to 6 year time frame that is estimated for the ISCO/ERD approach.

- The results and lessons learned from the pre-investigation and the pilot tests may help better estimate the volumes that require treatment and the amount of oxidant or nutrient that is appropriate. The IDR team believes that the findings from the pilot tests could result in revisiting the selected remedy for the source area.

- Reported relatively high sulfate concentrations in site ground water may accelerate electron donor consumption and may become a limiting factor for successful reductive dechlorination. Furthermore, in the absence of sufficient alkalinity, the pH may decrease, inhibiting bacterial growth, and limiting reductive dechlorination.

- Significantly fewer injection points may be required for establishing the biobarriers for the <u>shallow plume periphery and deep plume</u> if preferential injection into thin but highly permeable zones occurs.

- Some of the direct-push ground water samples that have helped define the deep plume may be the result of contamination that was brought down to deeper intervals during sampling rather than contamination that has migrated under natural conditions. As a result, the vertical and horizontal extent of the deep plume may have been overestimated. Installation and sampling of deep monitoring wells can help determine if the plume is accurately delineated.

Based on the above findings, the IDR team presents a discussion on remedial strategy and remedy implementation. The discussion highlights the following items.

- The results from the pre-design investigation and pilot studies could have substantial affect on the remedy design and could warrant revisiting the selected remedy for the source zone. The IDR team suggests reviewing the data from these studies and revisiting the remedy selection process before proceeding with design of the selected remedy. The IDR team can assist with reviewing the data and provide a valuable third-party, technical perspective.

- Injection of oxidants or nutrients for the shallow plume core and hot spot remedy might be efficiently accomplished through trenches or horizontal wells. In addition, the amount of oxidant or nutrient that might be needed is likely less than estimated in the Feasibility Study due to preferential flow through the thin sand lenses. The estimated costs for injections (both materials and labor) may be higher than needed. Depending on the outcome of the pilot studies, ERD rather than ISCO with ERD polishing, may be more appropriate for remediating this zone.

- The preferred flow of water, contamination, and injected nutrients through the thin sand lenses could substantially reduce the estimate amount of nutrients and the number of injection points for implementing ERD in the shallow plume periphery and deep plume. This could affect remedy cost, but it can also affect remedy performance. The injection of too much donor can also result excessive organic acids that could lower the pH and inhibit ERD.

- The IDR team believes that the remediation time estimates presented in the ROD appear optimistic for a heterogeneous subsurface with clays and may bias remedial decisions. PCE and its degradation products have diffused into clay material for nearly 40 years. Based on experience at other sites, the IDR team believes that contamination that has diffused into the clay will continue to contribute dissolved contamination to the more transmissive zones for decades. The IDR team suggests that the site team adjust its expectations for the remedy time frame to avoid the potential for moving away from an ERD biobarrier remedy that is working.

- The cost for the ERD biobarrier remedy will be highly dependent on how long the biobarrier lasts between injections. The site team has estimated that injections will be needed every 15 months. The pilot study results will help determine if this frequency is appropriate.

- The cost for the ERD biobarrier remedy will also be highly dependent on the true extent of the deep plume. Results from the pre-design investigation will help define the true extent of the deep plume and volume that requires remediation.

In addition to the above strategy-related recommendations, the IDR team provides the following items for consideration with respect to implementation.

- Given the heterogeneous nature of the site and the importance of stratigraphy for interpreting the site conceptual model, use rotosonic drilling during pre-design activities to obtain better cores for analysis.

- When planning for the ERD injections, consider the use of extracted ground water, rather than potable water.

- The IDR team provides specific suggestions for monitoring well locations and depth intervals. Suggestions are also provided to conduct pumping tests in specific wells.

- The IDR team suggests that data validation be limited during the long-term monitoring program given that data collected during the Remedial Investigation, data collected during pre-design activities, and a long record of long-term monitoring data will be available to help determine the validity of individual samples.

FIGURES

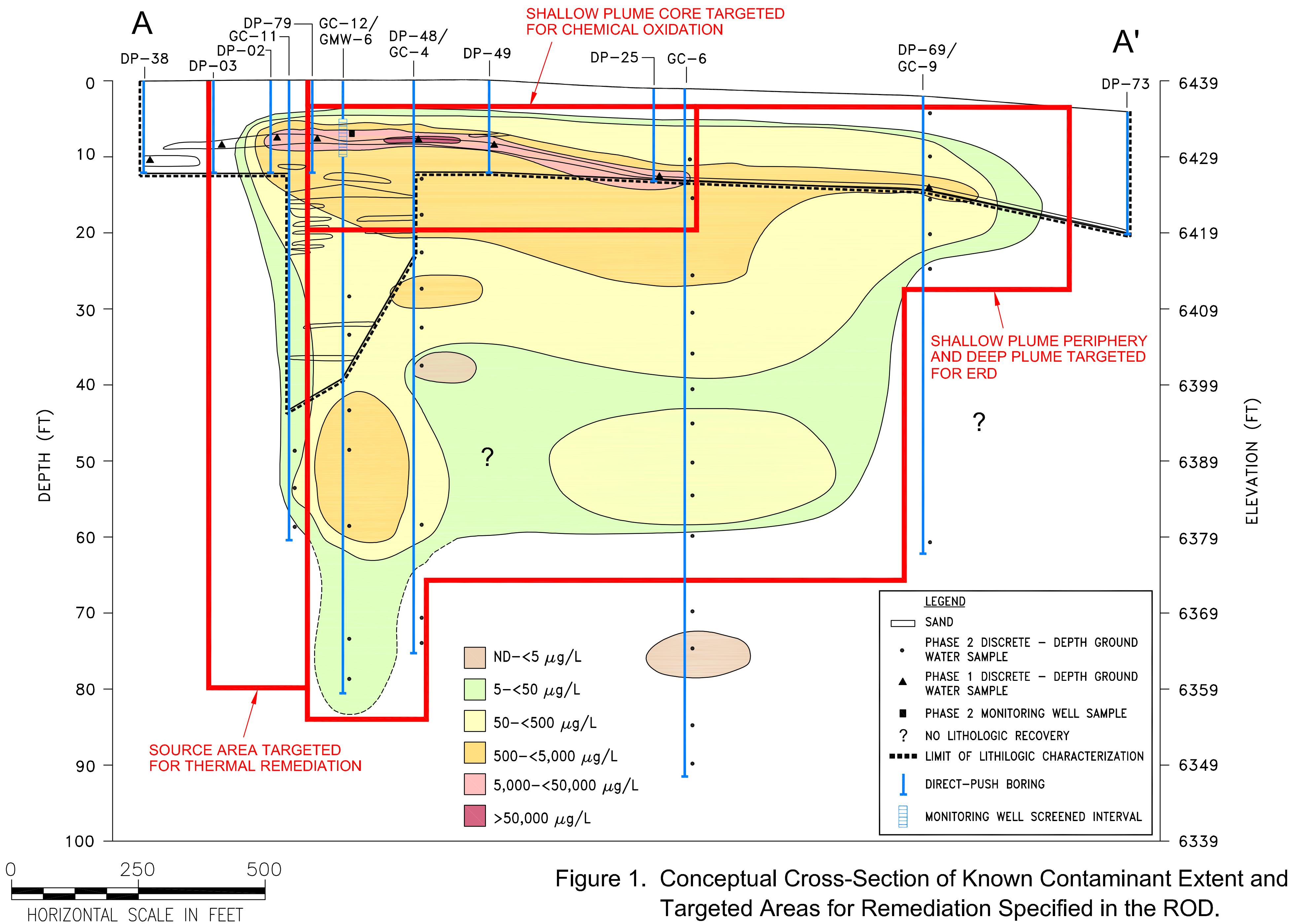

Figure 1. Conceptual Cross-Section of Known Contaminant Extent and Targeted Areas for Remediation Specified in the ROD.

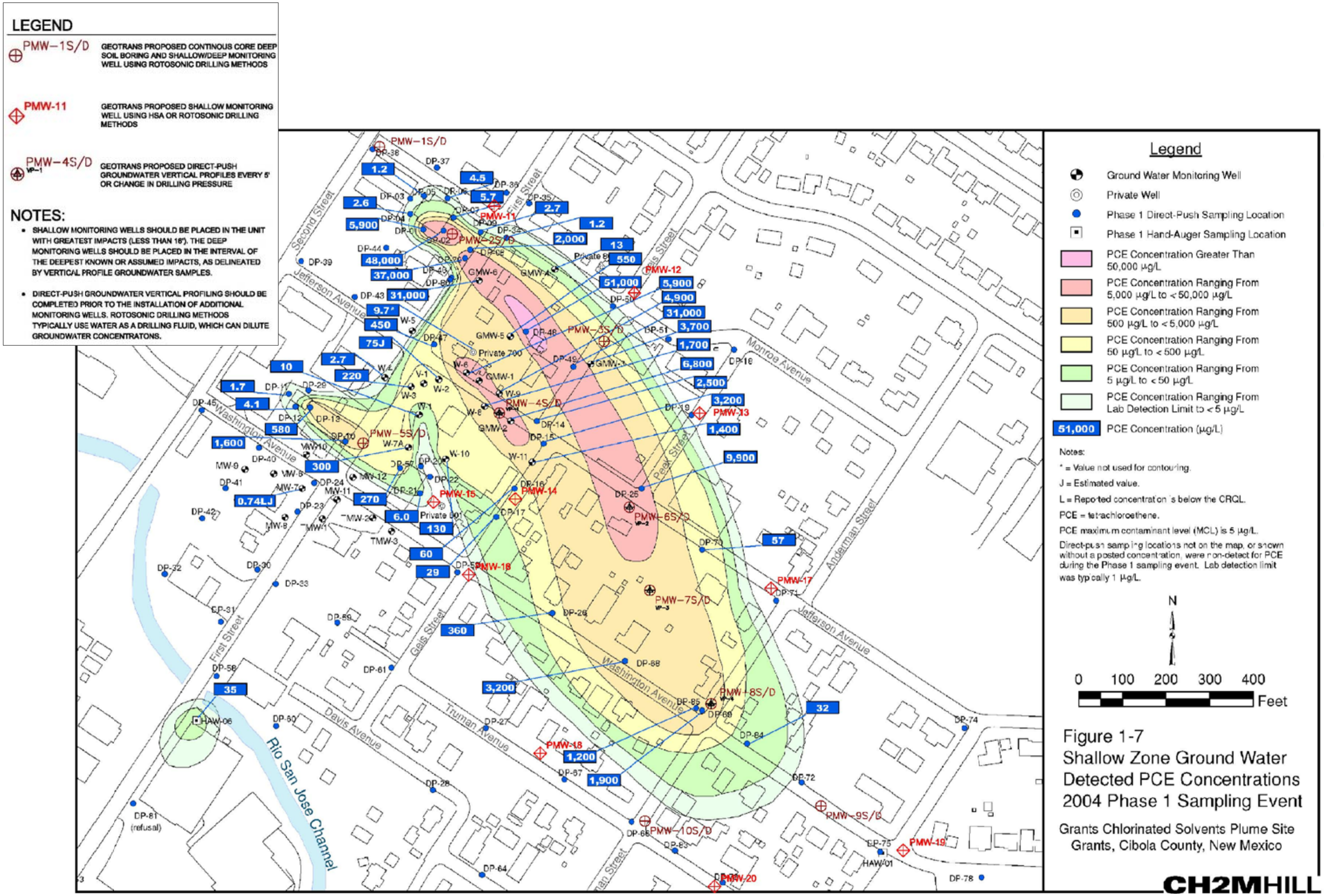

Figure 2. Proposed Soil Boring/Monitoring Well Locations.

ATTACHMENT A

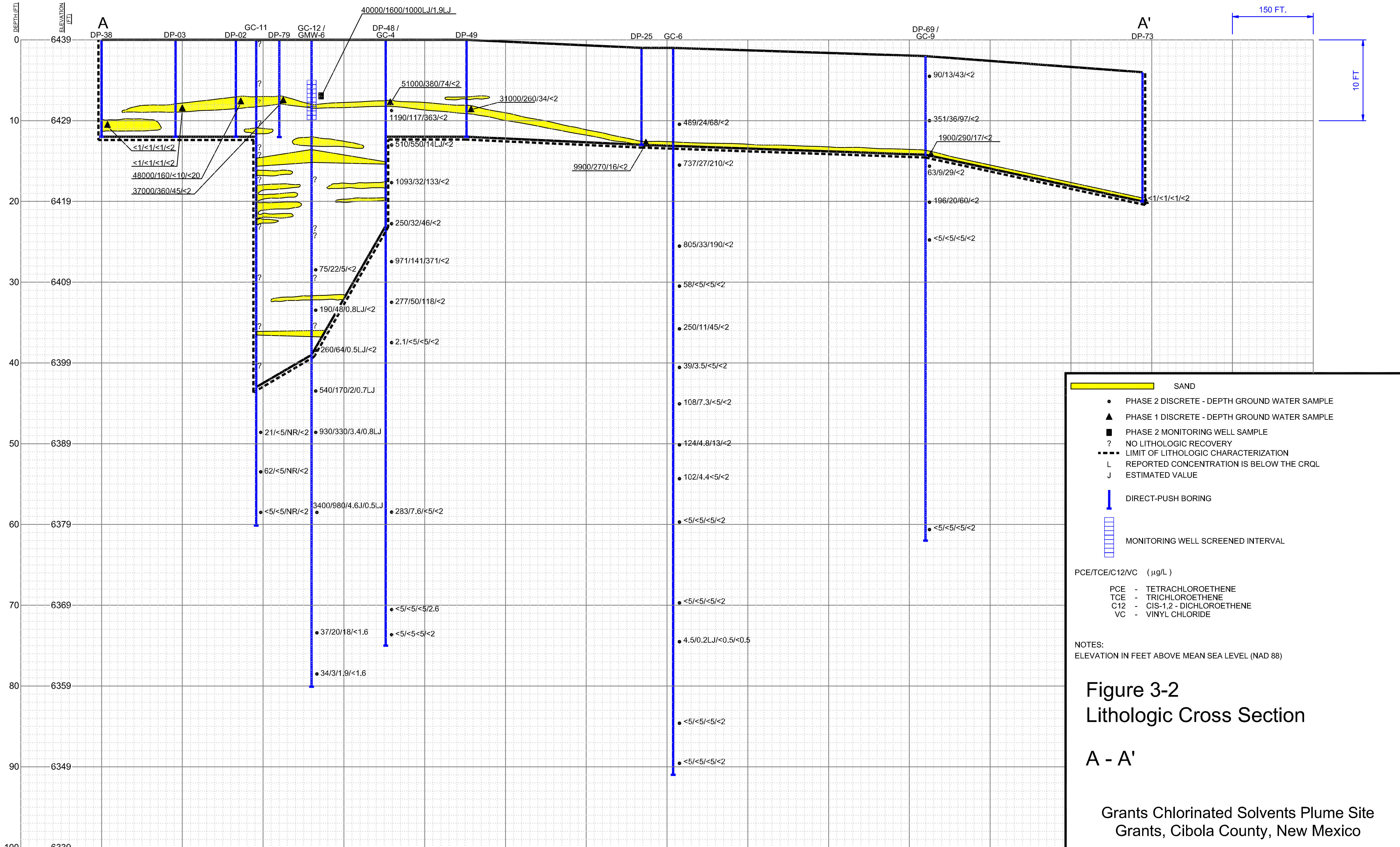

Figure 3-2
Lithologic Cross Section

A - A'

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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DP-01	2-Ft	2-Ft (CLP)	5 Ft	5 Ft (CLP)	10 Ft
PCE	0.62	0.044	0.68	0.140	8.3
TCE	<0.05	<0.012	<0.05	<0.012	<0.05
C12	<0.05	<0.012	<0.05	<0.012	<0.05
VC	<0.1	<0.012	<0.1	<0.012	<0.1
B	<0.05	<0.012	<0.05	<0.012	<0.05
T	<0.05	<0.012	<0.05	<0.012	<0.05
E	<0.05	<0.012	<0.05	<0.012	<0.05
X	<0.05	<0.012	<0.05	<0.012	<0.05

DP-04	2-Ft	5-Ft	10 Ft
PCE	0.26	0.069	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-05	2-Ft	5-Ft	10 Ft
PCE	0.17	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-06	2-Ft	5-Ft	10 Ft
PCE	0.18	0.4	0.053
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-07	2-Ft	5-Ft	10 Ft
PCE	0.073	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-13	2-Ft	5-Ft	10 Ft
PCE	8.7	5.7	0.31
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-29	2-Ft	5 Ft	10 Ft
PCE	0.053	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-34	2-Ft	5-Ft	10 Ft
PCE	<0.05	<0.05	<0.05
TCE	<0.05	0.21	0.06
C12	<0.05	0.068	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP 08	2-Ft	5-Ft	10 Ft
PCE	0.077	21	7.9
TCE	0.1	0.39	0.14
C12	0.56	0.15	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-02	2-Ft	2-Ft (CLP)	5 Ft	5 Ft (CLP)	10 Ft
PCE	1.5	0.120	36	14	15
TCE	<0.05	0.006LJ	0.07	0.025	<0.05
C12	<0.05	<0.012	<0.05	<0.013	<0.05
VC	<0.1	<0.012	<0.1	<0.013	<0.1
B	<0.05	<0.012	<0.05	<0.013	<0.05
T	<0.05	<0.012	<0.05	<0.013	<0.05
E	<0.05	<0.012	<0.05	<0.013	<0.05
X	<0.05	<0.012	<0.05	<0.013	<0.05

DP-12	2-Ft	5-Ft	10 Ft
PCE	1.2	1.7	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-10	2-Ft	5-Ft	10 Ft
PCE	0.14	0.076	1.4
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP 14	2 Ft	2 Ft (CLP)	5 Ft	5 Ft (CLP)	10 Ft
PCE	<0.05	<0.012	0.55	0.031	2.7
TCE	0.4	0.038	0.53	0.093	0.35
C12	0.35	0.042	0.14	0.038	0.057
VC	<0.1	<0.012	<0.1	<0.013	<0.1
B	<0.05	<0.012	<0.05	<0.013	<0.05
T	<0.05	<0.012	<0.05	<0.013	<0.05
E	<0.05	<0.012	<0.05	<0.013	<0.05
X	<0.05	<0.012	<0.05	<0.013	<0.05

DP-32	2 Ft	5-Ft	10 Ft
PCE	<0.05	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	0.34
X	<0.05	<0.05	0.17

DP-15	2 Ft	5-Ft	10 Ft
PCE	0.18	3.6	1.1
TCE	0.074	0.52	0.33
C12	<0.05	0.12	0.067
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-31	2-Ft	5-Ft	10 Ft
PCE	<0.05	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

DP-30	2-Ft	5-Ft	10 Ft
PCE	<0.05	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.5	<0.05

DP 57	2-Ft	5-Ft	10 Ft
PCE	<0.05	<0.05	0.066
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	0.065	<0.05	<0.05
E	0.38	<0.05	<0.05
X	1.8	<0.05	<0.05

DP 16	2 Ft	2 Ft (CLP)	5 Ft	5 Ft (CLP)	10 Ft
PCE	0.062	0.120	0.1	14	0.05
TCE	<0.05	0.006LJ	0.063	0.025	<0.05
C12	<0.05	<0.013	<0.05	0.005LJ	<0.05
VC	<0.1	<0.013	<0.1	<0.013	<0.1
B	<0.05	<0.013	<0.05	<0.013	<0.05
T	<0.05	<0.013	<0.05	<0.013	<0.05
E	<0.05	<0.013	<0.05	<0.013	<0.05
X	<0.05	<0.013	<0.05	<0.013	<0.05

DP-56	2-Ft	5 Ft	10 Ft
PCE	0.095	NA	NA
TCE	<0.05	NA	NA
C12	<0.05	NA	NA
VC	<0.1	NA	NA
B	<0.05	NA	NA
T	<0.05	NA	NA
E	<0.05	NA	NA
X	<0.05	NA	NA

DP-54	2-Ft	5-Ft	10 Ft
PCE	<0.05	NA	NA
TCE	<0.05	NA	NA
C12	<0.05	NA	NA
VC	<0.1	NA	NA
B	<0.05	NA	NA
T	<0.05	NA	NA
E	0.14	NA	NA
X	0.62	NA	NA

DP 21	2 Ft	2 Ft (CLP)	5-Ft	5-Ft (CLP)	10-Ft
PCE	1	0.160	0.24	0.034	<0.05
TCE	<0.05	<0.012	<0.05	0.003LT	<0.05
C12	<0.05	<0.012	<0.05	<0.013	<0.05
VC	<0.1	<0.012	<0.1	<0.013	<0.1
B	<0.05	<0.012	<0.05	<0.013	<0.05
T	<0.05	<0.012	<0.05	<0.013	<0.05
E	<0.05	<0.012	<0.05	<0.013	<0.05
X	<0.05	<0.012	<0.05	<0.013	<0.05

DP-22	2-Ft	5 Ft	10 Ft
PCE	0.082	<0.05	<0.05
TCE	<0.05	<0.05	<0.05
C12	<0.05	<0.05	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

Legend

DP-08	2-Ft	5-Ft	10 Ft
PCE	0.077	21	7.9
TCE	0.1	0.39	0.14
C12	0.56	0.15	<0.05
VC	<0.1	<0.1	<0.1
B	<0.05	<0.05	<0.05
T	<0.05	<0.05	<0.05
E	<0.05	<0.05	<0.05
X	<0.05	<0.05	<0.05

Soil Sampling Location and Depths (Concentrations in mg/kg)

GCSP Site Boundary

Phase 1 Direct-Push Soil Sampling Location

Notes:

Soil sampling locations shown on the map without posted laboratory results were non-detect for the summarized analytes.

(CLP) = CLP Lab Split Sample Results.

PCE = Tetrachloroethene.

TCE = Trichloroethene.

C12 = Cis-1,2-Dichloroethene.

VC = Vinyl Chloride.

B = Benzene.

T = Toluene.

E = Ethylbenzene.

X = Total Xylenes.

Refer to Table 5-6 for soil sampling results and explanation of data qualifiers.

Figure 5-2
Soil Sampling Summary of Results

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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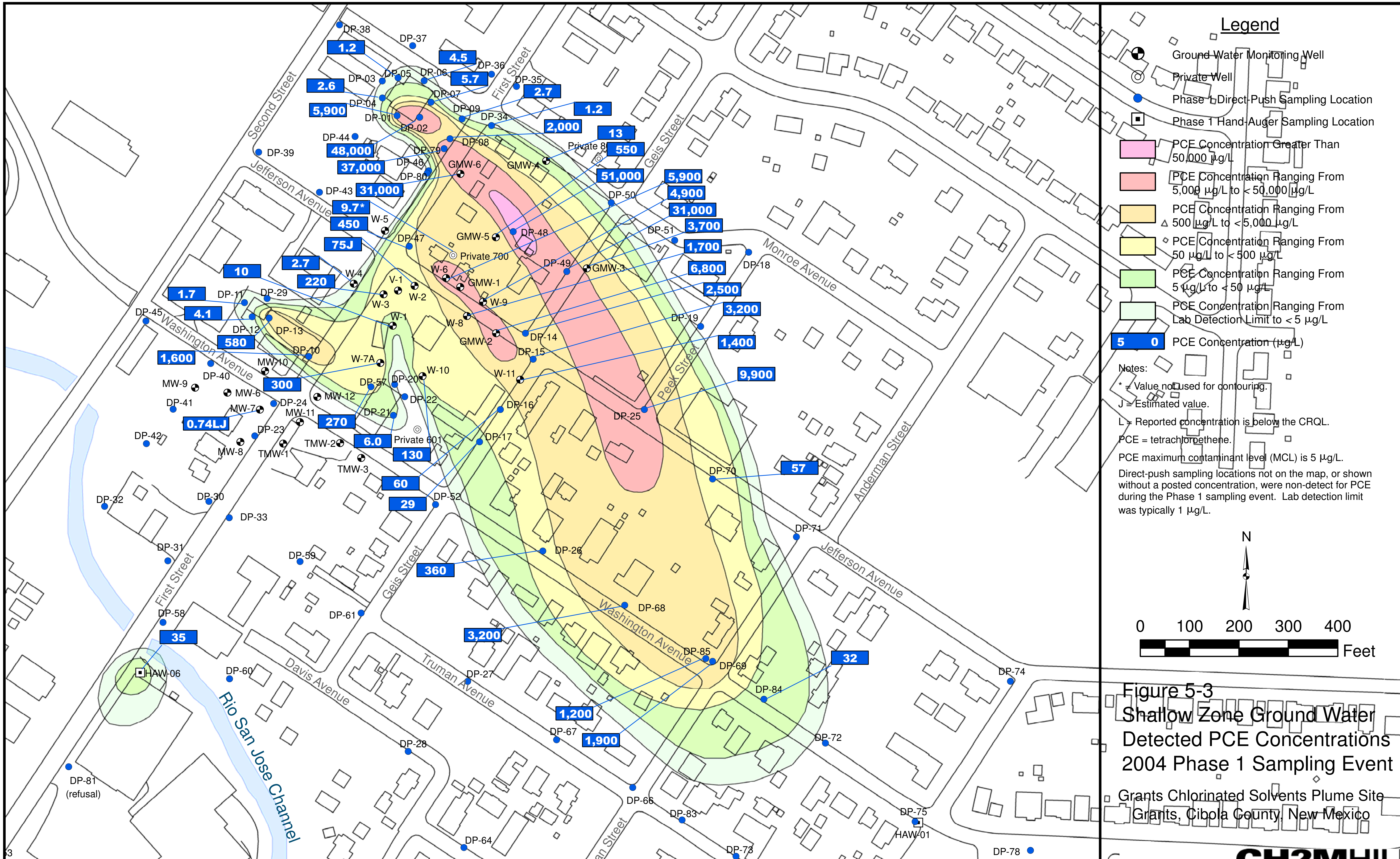

Figure 5-3
Shallow Zone Ground Water
Detected PCE Concentrations
2004 Phase 1 Sampling Event

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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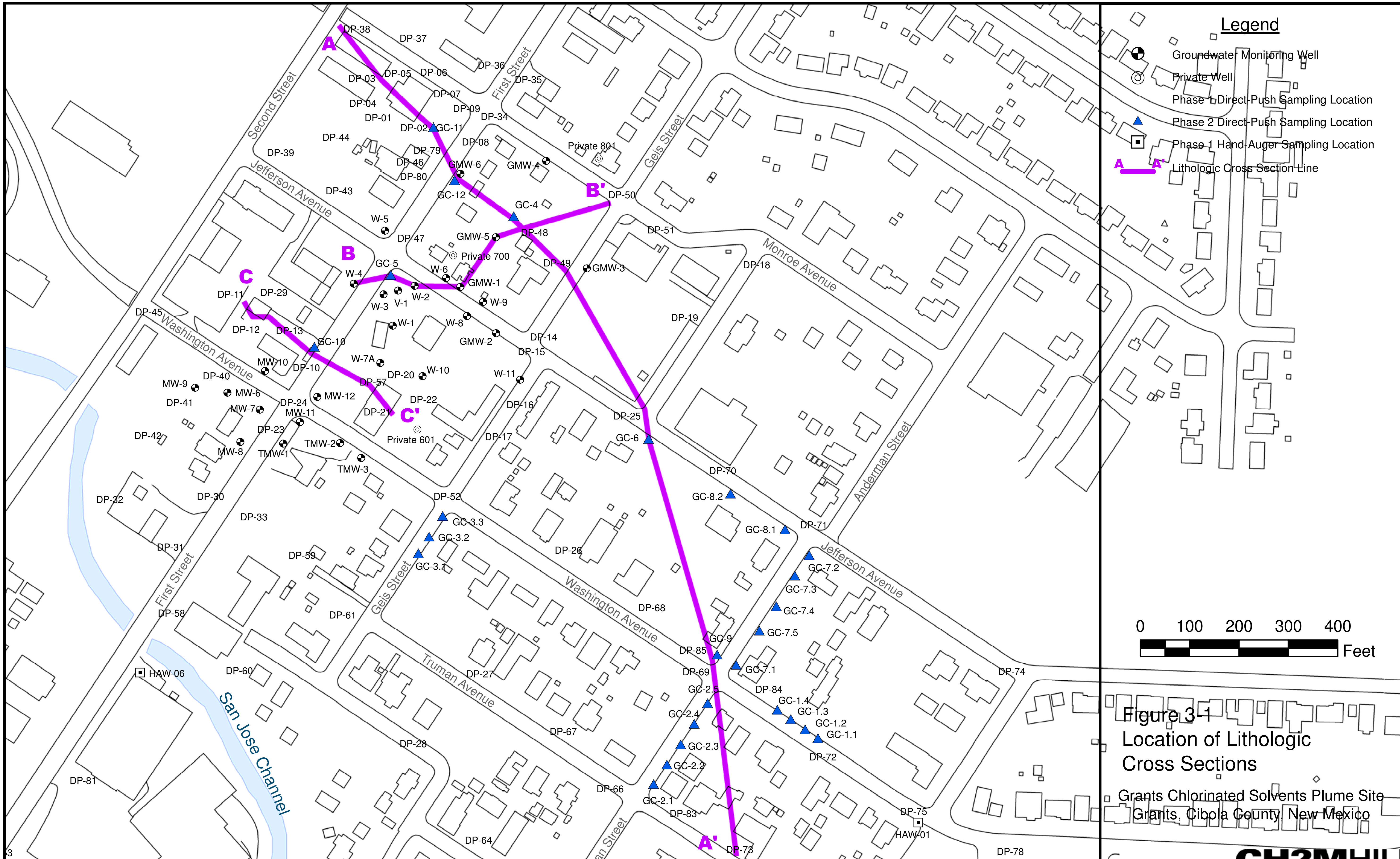

Figure 3-1
Location of Lithologic
Cross Sections

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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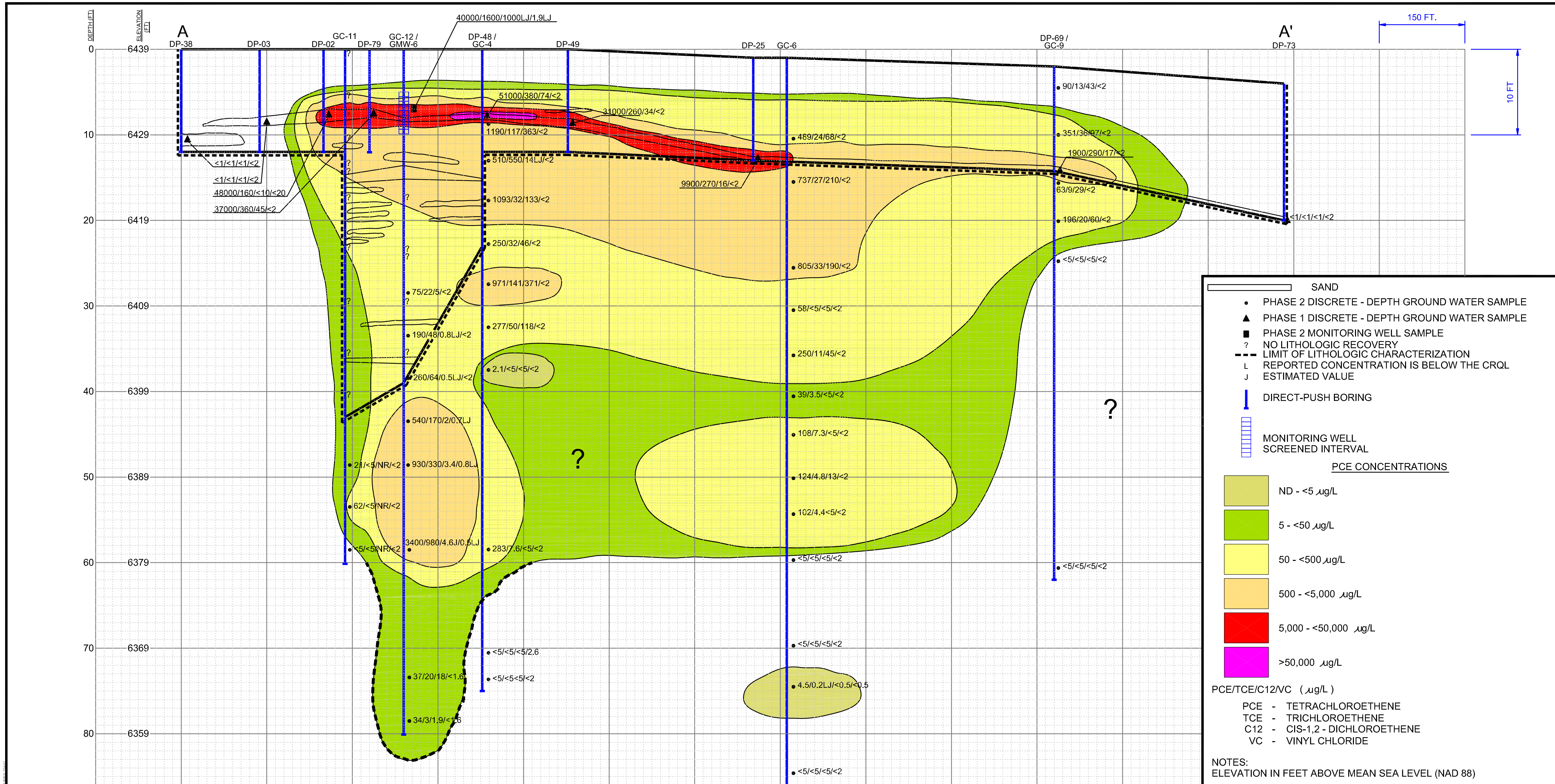

Figure 5-12
Vertical Profile of PCE Contamination

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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Figure 11
Structures With Vapor Intrusion Mitigation Systems

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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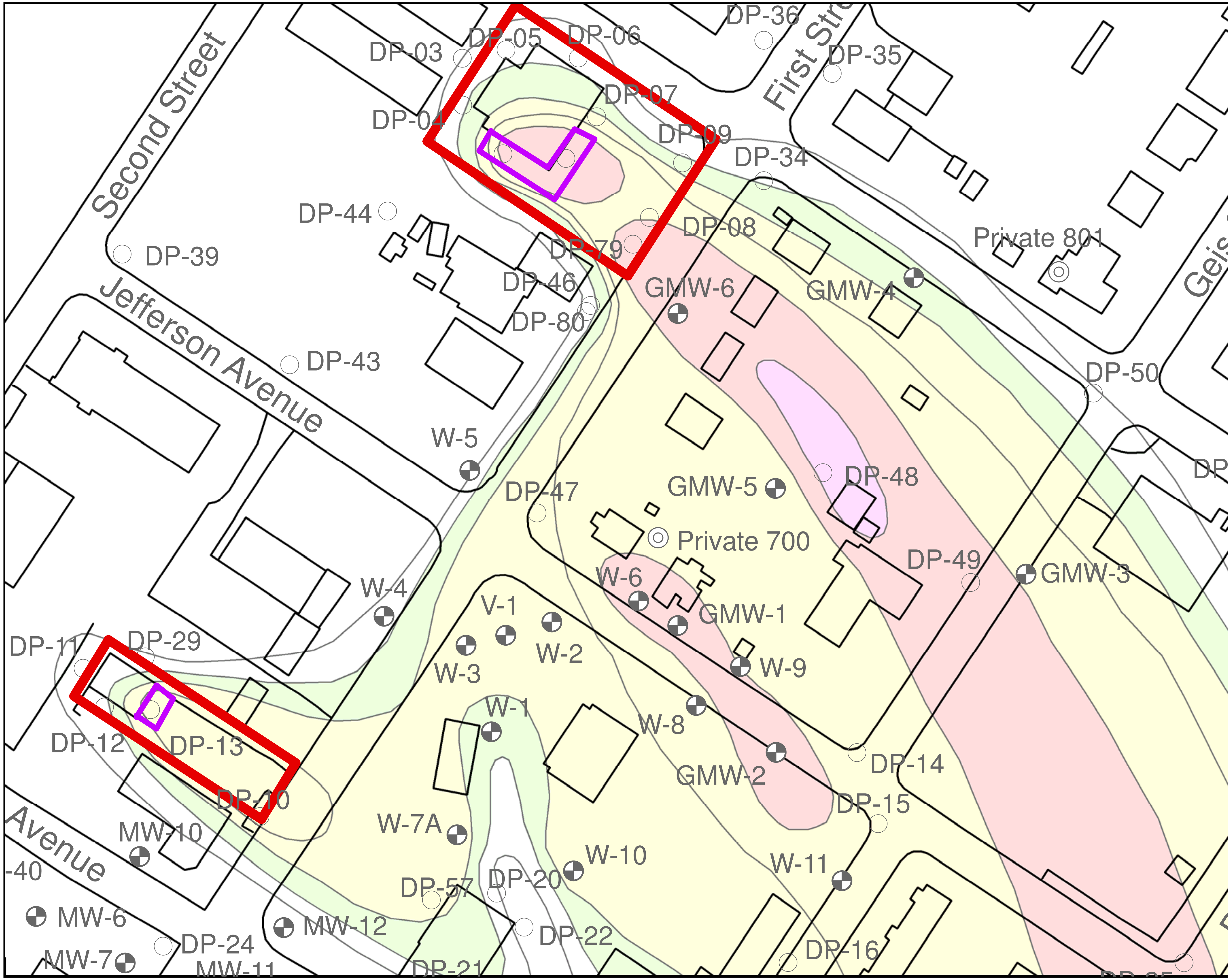

Figure 12
Extent of Source Area Treatment
Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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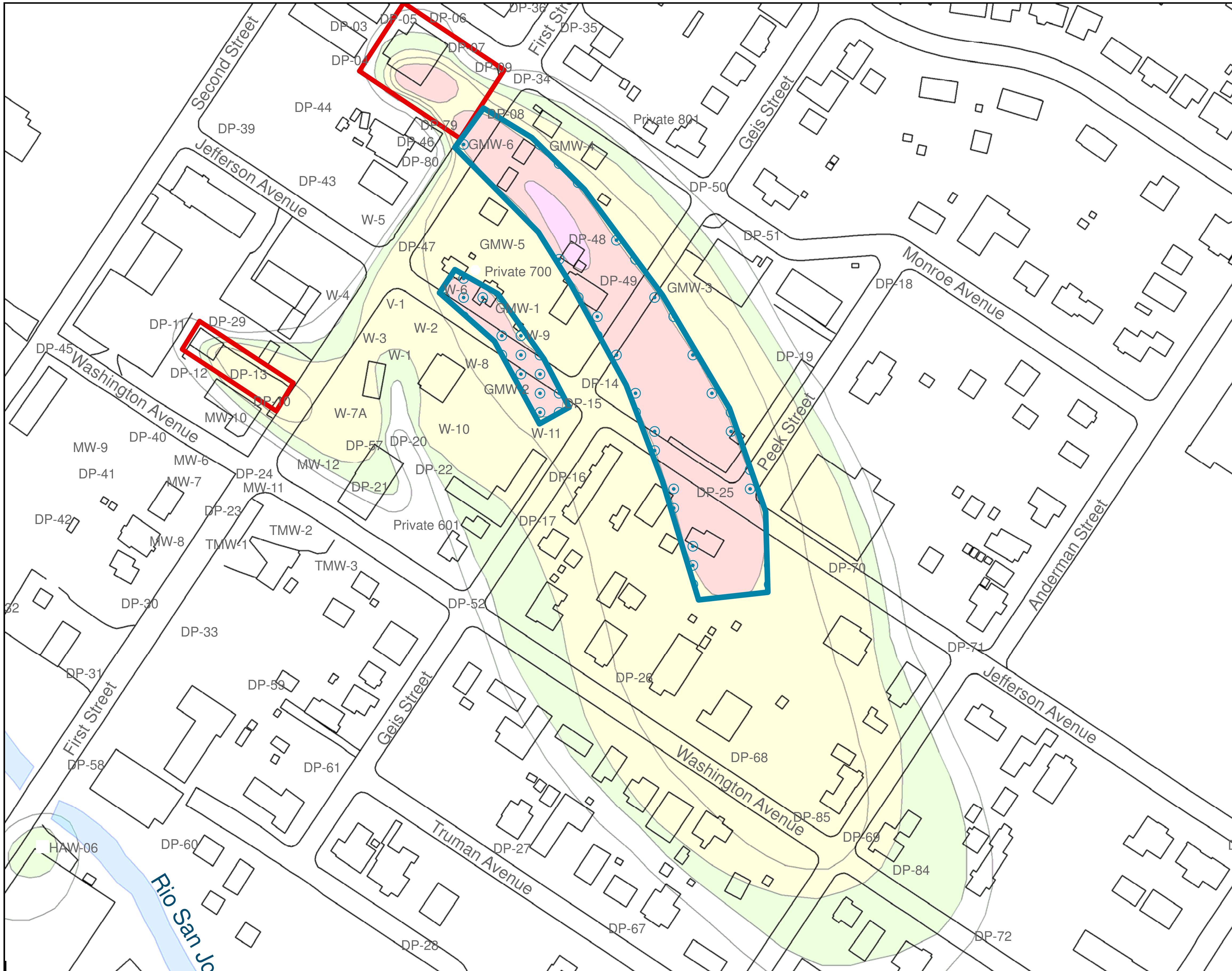

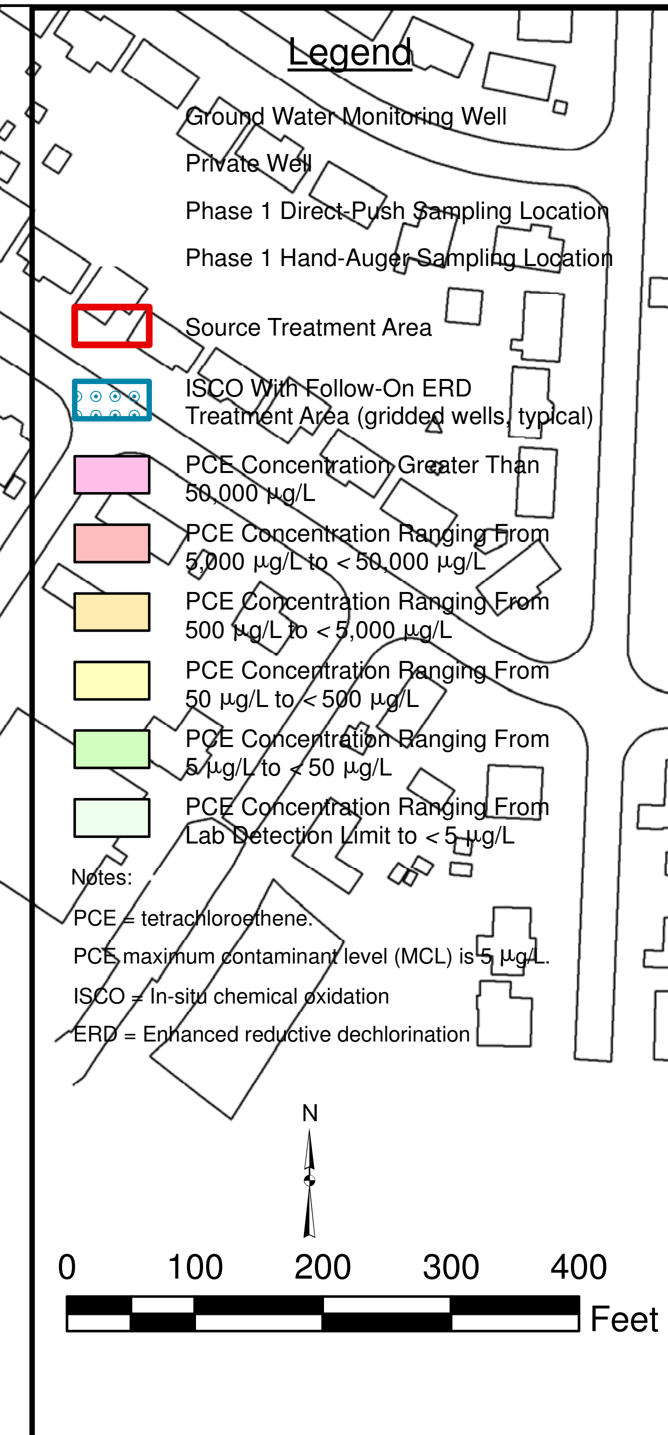

Figure 13
Conceptual Layout of
ISCO with Follow-On ERD
(Shallow Plume Core)

Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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21

Figure 14
Conceptual Layout of ERD Bio-Barrier (Shallow Plume Core)
Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico
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Figure 15
Conceptual Layout of ERD Bio-Barrier (Shallow Plume Periphery)
Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico

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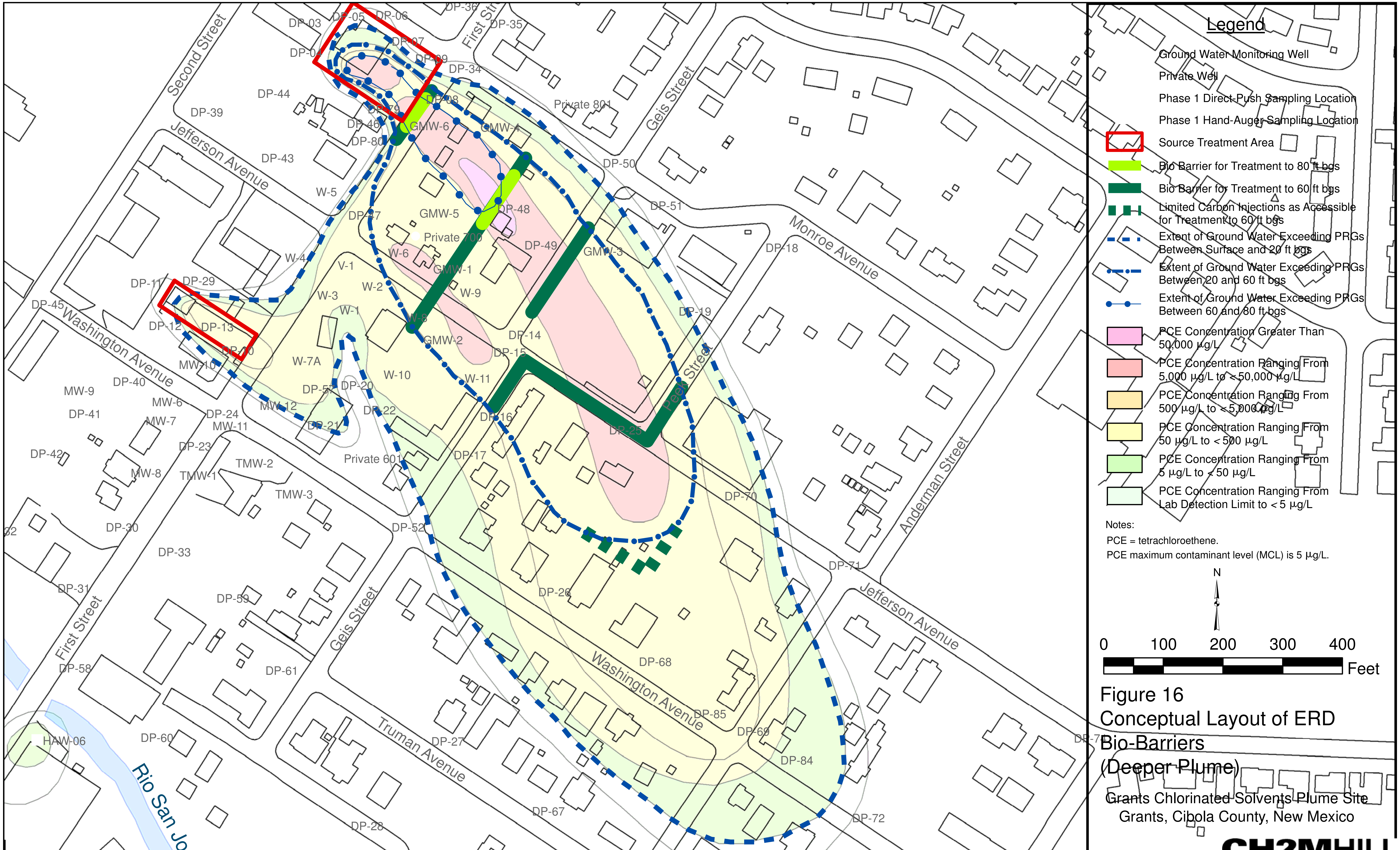

Figure 16
Conceptual Layout of ERD Bio-Barriers (Deeper Plume)
Grants Chlorinated Solvents Plume Site
Grants, Cibola County, New Mexico
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