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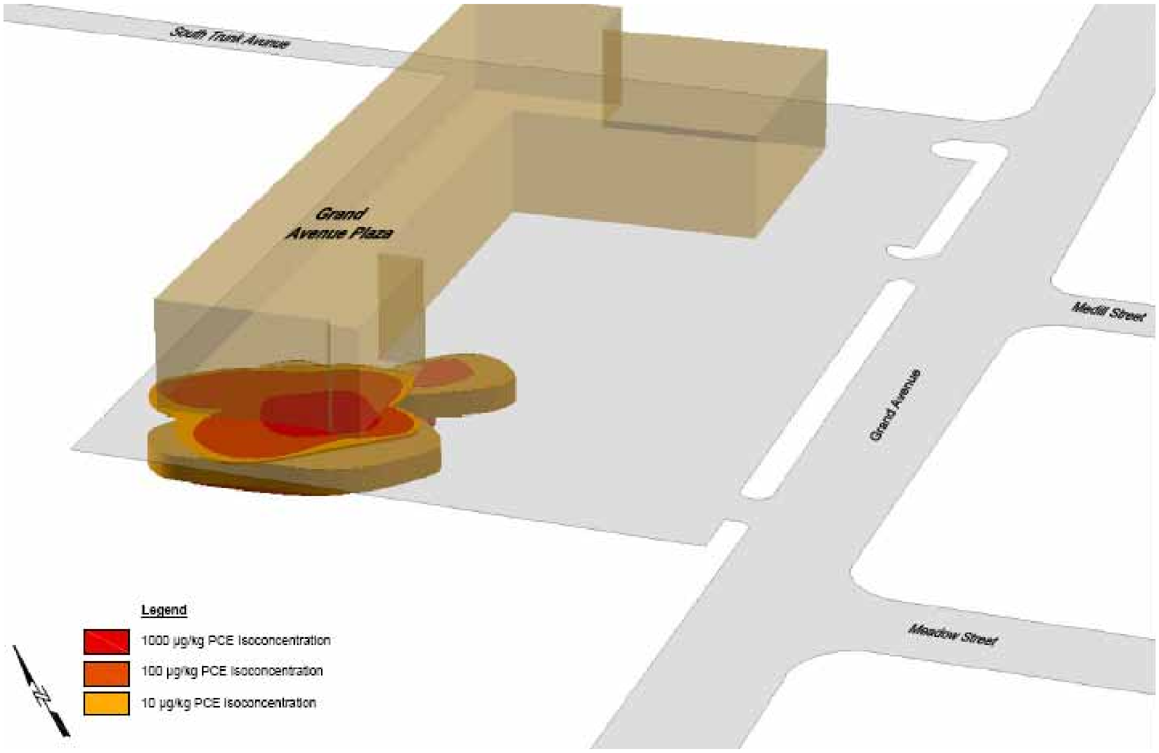
Grand Plaza Site Investigation Using the Triad Approach and Evaluation of Vapor Intrusion



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Grand Plaza Site Investigation Using the Triad Approach and Evaluation of Vapor Intrusion

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

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Foreword

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Sally C. Gutierrez, Director
National Risk Management Research Laboratory

Abstract

This document provides a detailed report about a field study conducted by EQM/URS on behalf of EPA/NRMRL to characterize the subsurface contamination of volatile organic compounds (VOCs) at a Brownfield commercial site. The TRIAD approach was implemented to characterize the extent of soil, groundwater, and soil gas contamination. These data were used to assess impact on indoor air due to vapor intrusion. Seventy-seven soil samples, twenty-eight groundwater samples, and ten soil-gas samples were collected from Geoprobe™ borings and analyzed on-site by USEPA Method SW-846 8265 direct sampling ion trap mass spectrometry (DSTIMS). Additional SW-8260b and TO-15 analyses were performed on approximately 10% of the samples by off-site laboratories. Tetrachloroethylene (PCE), trichloroethylene (TCE) and cis-1,2-dichloroethylene (DCE) were detected in all media with PCE as the prevalent compound.

The on-site analyses for PCE were 22% higher than the off-site analyses for methanol extracts from soil samples. For the shallow soil-gas samples, the on-site results for PCE agreed with the off-site analyses within about one order of magnitude for the sample pairs where PCE was present at concentrations >10 ppbv. The off-site results for the sub-slab soil-gas samples were several orders of magnitude higher than the on-site results, perhaps due to limitations in the on-site sampling and analytical approach at these high concentrations. The geology was interpreted from the boreholes and logs from previously drilled groundwater monitoring wells. All data indicated that there was a small PCE hot spot that was roughly 40 ft by 40 ft (12m by 12m). The hot spot was shallow (less than 10 feet [3m] below ground surface [bgs]) on top of a low permeability clay under the southwestern edge of the building where a drycleaner was once located.

Canister samples of indoor air were collected in April and August of 2005. The results were compared with shallow soil-gas and sub-slab soil-gas results to assess the impact of this contamination on the indoor air. PCE concentrations in the five indoor air samples ranged from 3.7 to 16 ppbv, with four of five results between 10 and 16 ppbv. For comparison, the ambient air contained 0.11 ppbv. The six samples of shallow soil-gas collected at a depth of 5 feet (1.5 m) bgs directly within or near the building had from 39 to 780 ppbv of PCE. The highest of the three sub-slab soil-gas samples had 2,600,000 ppbv of PCE. The time-averaged indoor air concentration of 12 ppbv corresponds to a cancer risk of 2E-05 based on an inhalation unit risk (IUR) of 3.0E-06 per $\mu g/m^3$ and an occupational exposure scenario of 8 hr/day, 5 day/week, 50 week/yr for 25 years.

The productivity of the aquifer was evaluated at several monitoring wells using two methods: slug test and a constant discharge test. The results of both types of tests demonstrate that site well yields are significantly greater than the 150 gallons per day criterion used by the Texas Commission on Environmental Quality (TCEQ) to differentiate between Class 2 (potential) and Class 3 (non-potential) groundwater resources. Therefore, the shallow groundwater zone at this site is designated a Class 2 groundwater resource.

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Acronyms, Abbreviations, and Symbols

α	Alpha (attenuation factor)
α_{SG}	Alpha based on soil-gas data
ACH	Air changes per hour (hr^{-1})
bgs	Below ground surface
BSA	Brownfields Site Assessment
°C	Degrees Celsius
cfm	Cubic feet per minute
cm	Centimeter
CVC	Colorado Vintage Companies
DCB	Dichlorobenzene
DCE	Dichloroethylene
Dec	December
DL	Detection limit
DSITMS	Direct sampling ion trap mass spectrometry
dup	Duplicate
ECD	Electron capture detector
EPA	Environmental Protection Agency
ESA	Environmental site assessment
ft	Feet
ft^2	Square feet
g	Gram
GC	Gas chromatography
gpd	Gallons per day
gpm	Gallons per minute
He	Helium
Hg	Mercury
H_2O	Water
hr	Hour
HVAC	Heating, ventilation, and air conditioning
in.	Inches
IUR	Inhalation unit risk
Kg	Kilogram

Acronyms, Abbreviations, and Symbols (continued)

L	Liter
m	Meter
m^2	Square meters
m^3	Cubic meters
MCL	Maximum contaminant level
min	Minute
mL	Milliliters
MNA	Monitored natural attenuation
MPS	Multi-probe system
MSD	Municipal Setting Designation
mV	Millivolt
MW	Monitoring well
ND	Not detected
NIST	National Institute of Standards and Technology
O_2	Oxygen
Oct	October
ORP	Oxidation reduction potential
OSHA	Occupational Safety and Health Administration
ΔP	Pressure differential
Pa	Pascal (unit of pressure)
PCE	Tetrachloroethylene
PCL	Protective concentration levels
PID	Photo-ionization detector
ppbv	Part-per-billion on a volume basis
ppm	Part-per-million
PRT	Post-run tubing
PVC	Polyvinyl chloride
Q_{Bldg}	Ventilation air flow rate for building
QC	Quality control
Q_{soil}	Vapor intrusion flow rate into building
RPD	Relative percent difference
µS/cm	Micro-siemens per centimeter
SB	Soil boring
SF_6	Sulfur hexafluoride
SIM	Selective ion mode

Acronyms, Abbreviations, and Symbols (continued)

SVOCs	Semi-volatile organic compounds
TCE	Trichloroethylene
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TO	Toxic organic
TRRP	Texas risk reduction program
TX	Texas
μg	Micrograms
$\mu g/m^3$	Micrograms per cubic meter
US	United States
V	Volt
VC	Vinyl chloride
VI	Vapor intrusion
VOCs	Volatile organic compounds
X_{Bldg}	Tracer gas concentration in indoor air
X_{tracer}	Tracer gas concentration at source
YSI	Yellow Springs Instrument

Acknowledgments

This report was prepared under the direction of Dr. Michelle Simon, the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) project manager at the National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio. The work was performed under Field Evaluation and Technical Support (FEATS) Contract No. 68-C-00-186. The prime contractor was Environmental Quality Management (EQM); Mr. Robb Amick served as the Program Manager. This report was prepared by Mr. Bart Eklund, Mr. Robert Schafer, and Mr. Derek Peacock of URS Corporation under subcontract to EQM. Mr. Doug Kladder of Colorado Vintage Companies prepared Section 6 of the report.

The fieldwork was performed by the following individuals. From URS, Messers. Bart Eklund (Project Manager), Eric Anderson (Chemist), Derek Peacock (Engineer), Robert Schafer (Geologist), Robert Smith (Geologist), and Mark Sollman (Geologist). From Tri-Corders**,** Dr. William Davis (Chemist). From Colorado Vintage Companies**,** Mr. Doug Kladder (Engineer).

The cooperation and participation of the following people are gratefully acknowledged: Ms. Ann Grimes of the City of Dallas, Office of Economic Development, Brownfields Program; Mr. Mark Obeso, Assistant Director, City of Dallas Housing Department; and Mr. Mike Frew, Texas Commission on Environmental Quality, Brownfields Coordinator.

Executive Summary

The U.S. Environmental Protection Agency (U.S. EPA) undertook a project to characterize subsurface contamination and evaluate the potential for vapor intrusion (VI) at the Grand Plaza Shopping Center in Dallas, Texas. There is subsurface contamination of chlorinated solvents beneath the southwest end of the building, where a dry cleaning was once located. In recent years, a series of restaurants have occupied the space.

The site investigation built upon several past Brownfield Site Assessments (BSAs) previously completed at the site. Based on the past work, it was known that groundwater and shallow soil in the vicinity of the former dry cleaner is impacted by tetrachloroethylene (PCE), trichloroethylene (TCE), and cis-1,2-dichlorothylene (DCE). The concentrations of metals and SVOCs were below the applicable regulatory levels in both soil and groundwater samples and therefore were no longer considered chemicals of concern for the property.

First, an intensive site characterization effort was performed. A Triad approach was used; i.e., real-time or rapid response analytical data were used on-site to reach decisions. The general approach for site characterization was to collect soil, groundwater, and soil-gas samples using direct-push equipment – from both inside and outside of the building – and analyze the samples on-site using EPA Method 8265, direct sampling ion trap mass spectrometry (DSITMS). Analytical run times of approximately three minutes per sample allowed low ppb-level data to be generated at a rapid rate. Approximately 10% of all samples were also analyzed by off-site laboratories.

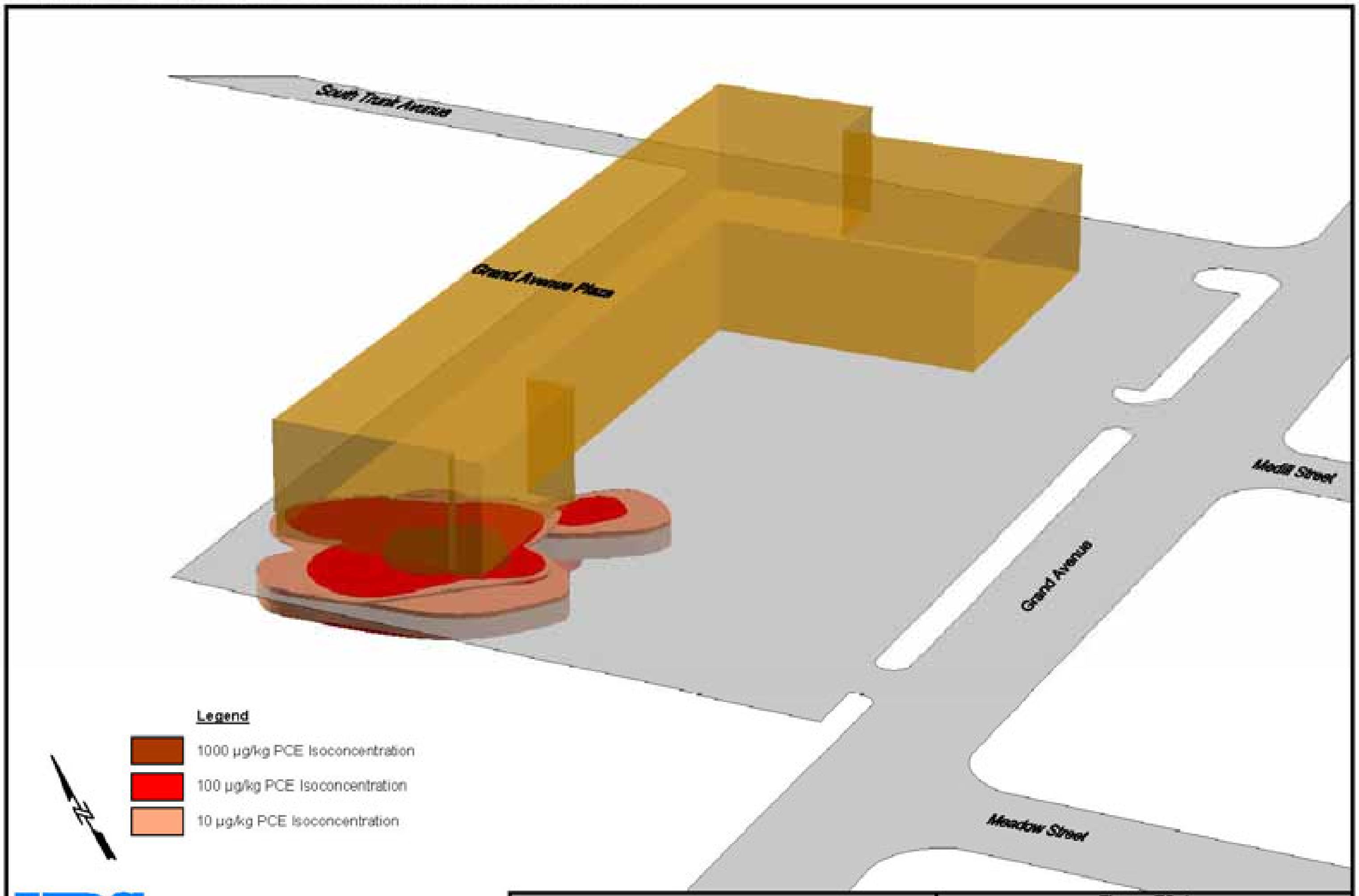
Drilling logs from the study area generally record the presence of silty clay deposits from 0 to 20 ft (0 to 6m) bgs, and fine- to coarse-grained sand deposits from 20 ft (6m) bgs to bedrock, the depth to which is highly variable within the area. The depth to bedrock varies from less than 20 ft (6m) bgs in the northeastern portion of the study area, to greater than 70 ft (30m) bgs in the northwestern portion of the study area. Within the study area, shallow groundwater is present at a depth of approximately 30 ft (9m) bgs within the sandy deposits of the terrace alluvium.

The site characterization effort indicated that the subsurface contamination was largely confined to a small area beneath the former dry cleaning business. All soil samples from outside the building were <0.4 ppm for all compounds. Contamination was detected in all borings down to a depth of 20 ft (6m) bgs. Soil samples from underneath the building contained up to 3.4 ppm of PCE, 2.3 ppm of TCE, and 6.4 ppm of DCE. The soil data for PCE are plotted in Figure ES-1. All groundwater concentrations outside the building were <0.1 ppm and all groundwater concentrations beneath the building were <0.4 ppm. The groundwater and soil data sets suggest that the PCE has undergone substantial degradation to TCE and DCE. No vinyl chloride (VC), however, was detected. In addition, benzene and toluene were not detected.

Aquifer production tests conducted at MW-7, MW-9, and MW-10 demonstrated well yields of 1,400 to 20,000 gpd (5,300 to 75,700 L/day) that are greater than the 150 gpd (570 L/day) criterion. Therefore, the groundwater at this site is designated Class 2 according to Texas regulatory guidance.

Shallow soil-gas samples were collected at six locations at a depth of 5 ft (1.5m) bgs and three sub-slab soil-gas samples also were collected. PCE in the shallow soil gas ranged from 0.039 to 0.71 ppmv. TCE concentrations were similar to the PCE concentrations, whereas DCE tended to be higher (up to 29 ppmv). The presence of TCE, DCE, and VC is additional evidence that the PCE has been degraded.

Soil-gas data at the site indicate a surprisingly large degree of spatial variability. The gas-phase subsurface contamination was found to exist in one relatively small "hot spot". The data suggest that the contamination has largely remained in place under the slab near its release point with only limited vertical and lateral transport.



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DATE: Sep 27, 2006
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3d_plumes.dwg

Figure ES-1
3-D PCE Plume
Based on April 2005
Soil Data

In conjunction with the site characterization, additional fieldwork was performed to evaluate vapor intrusion at the site. PCE was detected in multiple indoor air samples at about 12 ppbv (83 $\mu g/m^3$). Ambient air contained only 0.11 ppbv of PCE and does not appear to have been a significant source of this compound in the indoor air. The building ventilation rate was determined using a tracer gas. The measured values of 1 to 2 ACH at the Grand Plaza site appear to be relatively low for a restaurant, but are much higher than the default value of 0.25 ACH in the US EPA November 2002 guidance, which is based on the 10th percentile for single residence buildings.

The ratio of indoor air to soil-gas concentrations is often evaluated in vapor intrusion studies. This ratio typically is called the attenuation factor or α. Published values of α_{SG} tend to be <0.001. The EPA default α_{SG} value for screening purposes currently is 0.1, but is expected to decrease to 0.02 when the 2002 EPA guidance is revised sometime in 2007.

The three sub-slab soil-gas samples had 18,000,000; 26,000; and 59,000 $\mu g/m^3$ of PCE. The three indoor air samples had 85, 68, and 96 $\mu g/m^3$, for a mean of 83 $\mu g/m^3$. Therefore, $\alpha_{SG} = 5.3 \times 10^{-6}$ using the maximum values and $\alpha_{SG} = 1.4 \times 10^{-5}$ using the average values. The values of α_{SG} for other compounds detected in the sub-slab soil-gas are also in the 10^{-6} range using the maximum values.

The risk from inhalation of PCE at this site is conservatively estimated to be 2×10^{-5}, based on an inhalation unit risk for PCE of 3.0×10^{-6} per $\mu g/m^3$ and a 25-year occupational exposure scenario. The estimated risk falls within the 1×10^{-4} to 1×10^{-6} risk management range and there is no requirement for mitigation of vapor intrusion at this site based on State standards. A control system was designed as part of this study but ultimately was deemed to be not necessary. Future steps to achieve site closure are expected to involve seeking a Municipal Setting Designation (MSD) or a deed restriction for the site.

The results for this site have several implications for the standard regulatory approach for evaluating vapor intrusion. One, field investigations at sites with surface releases should include measurements in surface soil layers. Groundwater, soil, and soil-gas measurements at depth may not identify the maximum concentrations present at the site. The study illustrates the extreme spatial variability that is sometimes found in the subsurface at contaminated sites. Two, the use of mean values instead of maximum values may still be very conservative when soil-gas measurements are used to estimate indoor air concentrations using an α_{SG} of 0.1 or 0.02. Three, the U.S. EPA defaults for parameters such as Q_{soil}, Q_{Bldg}, and ΔP may be very conservative for a given site. Site-specific measurements can readily be performed to provide more accurate estimates for these parameters instead of relying on default values.

SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (U.S. EPA) undertook a project to characterize subsurface contamination and evaluate the potential for vapor intrusion (VI) at the Grand Plaza Shopping Center in Dallas, Texas. There is subsurface contamination of chlorinated solvents beneath the southwest end of the building, where a dry cleaning business was once located. URS Corporation (URS), under contract to EQM, directed the on-site activities.

The work was performed in two phases during 2005. During Phase I of the project, soil, groundwater, soil-gas, and indoor air samples were collected to characterize the extent of subsurface contamination at the site and evaluate the potential for vapors to enter the structure. The majority of analyses were performed on site using a mobile laboratory, with additional analyses performed off site to confirm and complement the on-site data. During Phase II of the project, additional indoor air measurements were performed and a system to control the vapors was designed.

The goals for the project were to:

1. Characterize the three-dimensional aspects of the chlorinated soil, groundwater, and soil-gas plume;
2. Determine the productivity of the local shallow aquifer;
3. Collect sub-slab soil-gas and indoor air data and use these data to evaluate vapor intrusion at the site; and
4. Design an active control system to limit vapor intrusion at the site.

The site characterization work was more thorough than is often the case at vapor intrusion sites. Therefore, the study provides a useful case study for this type of work.

SECTION 2
SITE DESCRIPTION

The site history is summarized below followed by a summary of previous site investigations and a short description of the geology and hydrology in the local area.

2.1 Site History

The area that was studied lies within a 26,189 ft^2 (2,433 m^2) single-story retail facility (strip mall) constructed in 1966 and its adjoining parking lot. The site is located at 3103 Grand Avenue in Dallas, Texas. It is in the South Dallas/Fair Park community about one mile south of the Texas Fairgrounds and the Cotton Bowl. The neighborhood is low income and economically underdeveloped.

The strip mall has spaces for nine to ten tenants. A combined Laundromat and dry cleaning business originally occupied the southwestern-most portion of the strip mall in a space that was roughly 30 ft by 70 ft (9m by 21m). The front and back views of the former dry cleaning business are shown in Figures 2-1 and 2-2.

Only limited information is available about the former dry cleaning business. The certificate of occupancy for Baccus Cleaners is dated October 3, 1966. The application to operate a dry cleaning establishment is dated April 8, 1970. The facility was categorized as a Class IV dry cleaning plant and authorized to store up to 50 gallons (190 L) of inflammable volatiles. A building permit for June 25, 1971 indicates that the site housed a coin-operated laundry with 30 washing machines and 15 dryers. An undated building plan indicates that two dry cleaning machines were located near the front, right corner of the business. A sump was located near the back of the business about 6 ft (2m) in from the back wall. The dry cleaning operation is believed to have operated from 1970 through 1986.

A series of restaurants later occupied the space that once housed the dry cleaning business. In recent years, a restaurant occupied both the former drycleaner space and the adjacent space, with a combined area of roughly 60 ft by 70 ft (18m by 21m). The two halves were connected via two French doors along an internal wall near the front of the building. The two spaces are shown in Figures 2-3 and 2-4 (a schematic is given in Section 3, Figure 3-4). At the time of the first phase of this study, neither space was occupied and the doors between them were open, allowing air to move freely between the two spaces. At the time of the second phase of this study, a new restaurant was operating in the 30 ft by 70 ft (9m by 21m) space that once housed the dry cleaning business and the adjacent space was unoccupied and closed off from the restaurant. The former dry cleaning facility currently is divided into three main rooms. The front room shown in Figure 2-3 provides public access to restaurant customers. The middle room or “fry room” has a large exhaust hood where food is prepared. The back room has a walk-in refrigerator and is used for dishwashing and storage. The back room also contains a small office partitioned off from the rest of the space. The fry room is shown in Figure 2-5 and the back room is shown in Figure 2-6.

2.2 Previous Site Investigations

The Grand Plaza Shopping Center was purchased in 1989 by a non-profit organization. The City of Dallas Brownfields Program provided a Phase I Environmental Site Assessment (ESA) for the property in 2001 as part of the process to secure funding for building improvements. The ESA identified several environmental concerns:

- On-site dry cleaning business in operation until 1986;
- Lumber treating plant in the 1950’s in operation adjacent to the property; and
- Underground gasoline storage tank at the lumber yard that occupied the adjacent property in the 1950’s.

Figure 2-1. Front View of Former Dry Cleaning Facility

Figure 2-2. Back View of Former Dry Cleaning Facility

Figure 2-3. Front Room of Former Dry Cleaning Facility

Figure 2-4. Dining Area Adjacent to Former Dry Cleaning Facility

Figure 2-5. Fry Room at Former Dry Cleaning Facility

Figure 2-6. Back Room at Former Dry Cleaning Facility

A Brownfields Site Assessment (BSA) was conducted by Leigh Engineering in April 2002 under the Voluntary Cleanup Program (VCP) of the Texas Commission on Environmental Quality (TCEQ). Based on the initial findings, a second BSA was conducted by Leigh Engineering in August 2002.

During the first BSA, four groundwater monitoring wells were installed and 22 soil samples were collected from seven soil boring locations (well locations are shown in Section 3, Figure 3-1). Samples were analyzed for metals, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). During the second BSA, a fifth downgradient monitoring well (MW–5) was installed. Subsequently, all five monitoring wells were sampled, a soil-gas sample was collected beneath the slab of the former dry cleaner, and a database search was conducted to identify any water wells within a 1/2-mile (800m) radius of the site.

The first four monitoring wells were installed to depths of roughly 35 ft to 60 ft (10.7m to 18.3m) below ground surface (bgs). The depth to groundwater was determined to be between 28 and 35 ft (8.5 to 10.7m) bgs with an apparent gradient sloping from west to east across the site. The bedrock elevations were between 73 and 68 ft (22.2 and 30.7m) bgs.

Analytical results from four of the groundwater monitoring wells (i.e., MW–1, –2, –4, and –5) indicated that the groundwater in the vicinity of the former dry cleaner was impacted by tetrachloroethylene (PCE), trichloroethylene (TCE), and/or cis-1,2-dichlorothylene (DCE).[1] Contaminants were not detected in the monitoring well farthest away from the former dry cleaner (MW–3).

Soil borings 1 through 4 were advanced to 14.5 to 15 feet (4.4 to 4.6m) through the concrete slab in the former dry cleaning facility using direct push technology. Soil borings 5 through 7 were advanced east and south of the dry cleaning facility to 15 feet (4.6m) using a hollow stem auger drilling. Shallow soil samples collected from the four borings beneath the floor of the former dry cleaner at depths of 2 feet (0.6m) and 4.5-6.5 ft (1.4 to 2.0m) contained PCE, TCE, and/or DCE. The highest concentrations were in the vicinity of SB-2 between 2.5 and 4.5 ft (0.76 and 1.4m).

Soil samples were also collected during the installation of the on-site monitoring wells. The samples were mostly non-detect, but PCE, TCE, and DCE were detected at low ppm-levels in shallow soils at some locations.

The concentrations of metals and SVOCs were below the applicable regulatory levels in both soil and groundwater samples and therefore were not considered chemicals of concern at the property. No water wells were located within a 1/2-mile (800m) radius of the site according to the database report.

Samples were collected from the five existing groundwater monitoring wells in July 2003 and analyzed for VOCs. Three additional groundwater monitoring wells (MW–6 through –8) were installed by URS in April 2004 and groundwater samples were collected at all eight wells in May 2004 and analyzed for VOCs. The 2004 results were similar to the results obtained in 2003 for the five existing wells. PCE, TCE, and cis-1,2-DCE were detected in the three new wells at concentrations slightly above the residential Protective Concentration Levels (PCLs).

2.3 Site Geology and Hydrogeology

During the Cretaceous period of the Mesozoic era, transgression and regression of the sea across north-central Texas deposited sediments on top of flat-lying Paleozoic age strata. Near the end of the Cretaceous period, regional uplift tilted the layers of sediment toward the east as seas withdrew toward the Gulf of Mexico. Subsequent transgression and regression of the sea deposited sediments of Tertiary and Quaternary age further to the east, as streams eroded the exposed land to the west and deposited terrace and alluvial sediments there (Nordstrom, 1982).

At the Grand Plaza Shopping Center, Quaternary age terrace alluvium (or soils formed therein) is exposed at ground surface, or lies beneath pavement and backfill material in this urban area. Regionally, these sediments are comprised of heterogeneous or interbedded gravel, sand, silt, and clay mixtures. Thickness of the alluvium is highly variable, but deposits are usually less than 75 ft (23m) thick (Nordstrom, 1982). Drilling logs from the study area generally record the presence of silty clay deposits

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[1] Compared with Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) for a 0.5-acre source area, commercial setting, and drinking water scenario.

from 0 to 20 ft (0 to 6m) bgs, and fine- to coarse-grained sand deposits from 20 ft (6m) bgs to bedrock, the depth to which is highly variable within the area.

The competent bedrock, which is unconformably overlain by the terrace alluvium, consists of Cretaceous age Austin Group deposits. Regionally, the Austin Group is comprised of chalk, limestone, marl, clay, and sand deposits. Sometimes referred to collectively as the Austin chalk, the Austin Group deposits can be up to 700 ft (200m) thick (Nordstrom, 1982). Drilling within the study area has penetrated only the first few inches of bedrock, so the nature of the Austin Group deposits there has not been defined in detail. However, one drilling log from the area describes the bedrock surface as light gray clayey silt, presumably weathered limestone or marl, that is calcareous (evidenced by its effervescence in hydrochloric acid), dry to damp, and hard. The depth to bedrock varies from less than 20 ft (6m) bgs in the northeastern portion of the study area, to approximately 75 ft (23m) bgs in the northwestern portion of the study area.

The terrace alluvium and Austin Group deposits are known regionally to produce only small quantities of groundwater. The important aquifers of the region are the Woodbine Group and the Twin Mountains Formation of the Trinity Group (Nordstrom, 1982). Like the Austin Group, both of these aquifers are Cretaceous in age. Other Cretaceous age stratagraphic units separate the Austin Group from the deeper aquifers, and the aquifers from one another. Beneath the study area, the depth to the Woodbine Group is approximately 850 ft (260m) bgs, and the depth to the Twin Mountains Formation is approximately 2,550 ft (780m) bgs (Nordstrom, 1982).

Within the study area, shallow groundwater is present at a depth of approximately 30 ft (9m) bgs within the sandy deposits of the terrace alluvium. The bedrock beneath the alluvium presumably forms a hydrologic barrier beneath the study area, but its influence on local groundwater flow has yet to be determined. The bedrock surface forms a trough that slopes to the northwest and west, but the apparent direction of groundwater flow, based on groundwater monitoring wells in the area, is to the east.

SECTION 3
TECHNICAL APPROACH

This section contains a description of the technical approach that was employed during the study. The schedule of field activities and study design are presented below, followed by brief summaries of the sampling, analytical, and sample handling procedures.

3.1 Schedule of Field Activities

The chronology of on-site events is shown in Table 3-1. All field activities were performed in the year 2005.

3.2 Study Design

The general sampling strategies employed during the initial site characterization work and the second round of indoor air sampling are described below. The approach used to install two additional groundwater monitoring wells, perform slug tests, and design a control system also are described.

3.2.1 Site Characterization

Target compounds were selected based on existing soil, groundwater, and soil-gas data collected in past site characterization efforts undertaken by TCEQ. The on-site monitoring addressed the six compounds shown in Table 3-2. PCE is a commonly used dry cleaning fluid and it is the primary compound of interest at this site. TCE, DCE, and vinyl chloride (VC) are thought to be present at the site due to anaerobic degradation of PCE. For the off-site analyses, the applicable standard target analyte list for each analytical method was employed, which included additional compounds beyond those shown in Table 3-2.

A sampling array was established over the site with spacing outside the building of roughly 33 ft by 33 ft (10m by 10m) and spacing inside the building of roughly 10 ft by 10 ft (3m by 3m). The sampling array is shown in Figure 3-1. The sampling array included eight rows of sampling points: A through H. Row “A” was behind the back of the building and Row “H” was along Grand Avenue. The potential sampling locations on each row were numbered from low to high in the southwest to northeast direction (i.e., sampling locations A1, B1, C1, etc. were along the southwest property boundary). Additional rows of potential sampling locations were established inside the building (e.g., Rows “M” through “S”). The sampling array included more potential locations than were actually sampled.

Direct-push drill rigs were used to collect samples. A 66DT unit mounted on a flat-bed truck was used outside the building and a dolly probe was used indoors. The two rigs are shown in Figures 3-2 and 3-3. Drilling was performed by ESN South of Corpus Christi, Texas under the supervision of two URS geologists. The drillers decontaminated non-dedicated sample equipment with soap and water and used high-pressure washers for large equipment. A Triad approach was used (USEPA, 2003a)(ITRC,

Figure 3-2. Large Direct-Push Rig

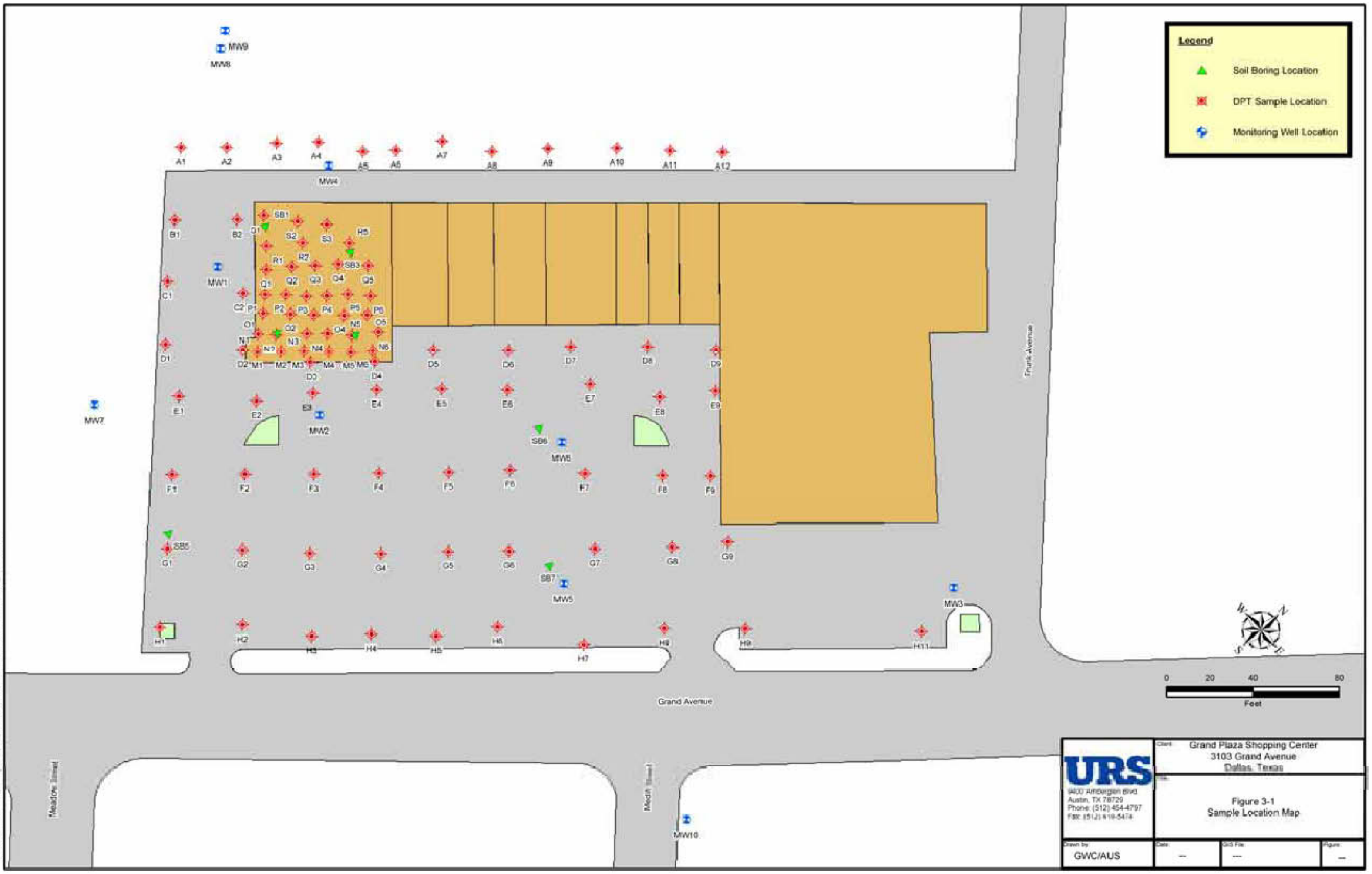

Figure 3-1
Sample Location Map

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Table 3-1. Schedule of Field Activities

Date	Activity
April 11 – 15	Collect soil, groundwater, and soil-gas sampling and use on-site analysis to characterize site. Collect indoor air and soil-gas samples for off-site analysis.
August 29	Install groundwater monitoring well MW–9.
August 29 – 30	Perform second round of indoor air sampling.
August 31	Inspect site for design of control system.
October 11	Install groundwater monitoring well MW–10.
October 20 – 21	Collect groundwater samples from 9 of 10 monitoring wells (no sample could be obtained from MW–2).
December 13 – 14	Collect groundwater samples from MW–2, –9, and –10.
December 13 – 14	Perform slug tests at MW–7, –9, and –10.

Table 3-2. Primary Compounds of Interest

Compound	CAS #	Synonyms	Molecular Weight	Conversion Factor for Air Samples
Tetrachloroethylene	127-18-4	PCE, Perk, perchloroethylene	165.8	1 ppb = 6.78 μg/m^3
Trichloroethylene	79-01-6	TCE	131.4	1 ppb = 5.37 μg/m^3
1,2-Dichloroethylene	156-59-2	cis-1,2-DCE	96.9	1 ppb = 3.97 μg/m^3
	156-60-5	trans-1,2-DCE		
Vinyl Chloride	75-01-4	VC, chloroethene	62.5	1 ppb = 2.56 μg/m^3
Benzene	71-43-2	--	78.1	1 ppb = 3.19 μg/m^3
Toluene	108-88-3	--	92.1	1 ppb = 3.77 μg/m^3

2003).[2] In this approach, real-time or rapid response analytical data is used on-site to reach decisions. The intent is to characterize the site with as few mobilizations as possible, so the on-site analytical capabilities are very important to the success of the approach. In this study, soil, groundwater, and soil-gas samples were collected using direct-push equipment and the samples were analyzed on-site. Analytical results were plotted at the site as they became available and used to make decisions about where to collect additional samples.

The depth to bedrock was obtained at 33 locations where probes were pushed, plus at eight existing monitoring wells near the building. Groundwater samples were obtained from five locations beneath the building and 23 locations outside the building. A total of 77 discrete soil samples were collected from 15 locations: 20 samples from four locations outside the building and 57 samples from 11 locations within the building. All soil samples were collected within or very near the building. Soil gas sampling was attempted at 24 locations. The general approach for evaluating vapor intrusion was to collect time-integrated soil-gas and indoor air samples in

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[2] The US EPA TRIAD approach is described at the following websites:
http://www.epa.gov/tio/triad/
http://www.clu-in.org/download/char/2004triadfactsheeta.pdf

Figure 3-3. Dolly Rig

evacuated, stainless-steel canisters for off-site TO-15 analyses.

3.2.2 Second Round of Air Monitoring

Based on the results of the initial site characterization, additional samples were collected to evaluate the potential for vapor intrusion. Indoor air samples were collected at two locations during the first round of sampling and at one location during the second round of sampling. The analyses were performed off-site.

Tracer gas tests were performed in conjunction with the second round of indoor air sampling. Pure sulfur hexafluoride (SF_6) was introduced into the sub-slab to verify that vapor intrusion was occurring. Pure helium was released within the building to measure the air exchange rate for the building. Measurement of helium inside the structure was performed to allow calculation of the ventilation air flowrate (Q_{Bldg}) using the ratio technique. Under steady-state conditions, the dilution of the tracer gas is equal to the ratio of the building ventilation and the tracer gas release rate:

$$Q_{Bldg} * X_{Bldg} = Q_{tracer} * X_{tracer} \qquad \text{(Eq. 3-1)}$$

Where:

Q_{Bldg} = ventilation air flowrate,
X_{Bldg} = tracer gas concentration in indoor air,
Q_{tracer} = tracer gas release rate, and
X_{tracer} = tracer gas concentration at source.

Q_{tracer} and X_{tracer} were known, and X_{Bldg} was measured in the field.

3.2.3 Installation of Groundwater Monitoring Wells

Two groundwater monitoring wells (MW–9 and MW–10) were installed in addition to the eight wells that already were present at the site. Hollow-stem auger drilling was used to advance boreholes and install threaded 2-in. (5 cm) diameter schedule-40 PVC casing, 0.010-in. (0.025 cm) factory-slotted PVC screen, and a threaded end cap. The annulus space around each well screen was filled with 20 × 40 mesh silica filter sand to a minimum of 2 ft (0.6m) above the top of the screen. The sand pack was sealed from the overlying annulus space with hydrated 3/8-in. (1 cm) bentonite pellets installed to just below ground surface. Wells were completed at ground surface with a flush-mounted 8-in. (20 cm) diameter manway housed within a concrete pad.

The drilling was performed by Groundwater Monitoring of Grand Prairie, Texas under the supervision of a URS geologist. One well (MW–10) was installed down-gradient of the former drycleaning facility along Medill Street near its intersection with Grand Avenue. This location was selected to help delineate the existing groundwater plume and was expected to be free of contamination. The second well (MW–9) was installed adjacent to the existing monitoring well, MW–8. The depth to bedrock in this area is approximately 76 ft (23m) bgs whereas MW-8 extends to only about 50 ft (15m) bgs. MW-9 was installed to extend to the top of the bedrock. Drilling logs for all ten monitoring wells are given in Appendix A.

3.2.4 Slug Tests

Slug tests were performed at MW–5, MW–7, and MW–9 using four and six ft (1.2 and 1.8m) long slugs constructed of 1-in. (2.5 cm) diameter PVC pipe filled with clean gravel and sealed with water-tight caps. The rise and fall of the water level during each test was measured using a pressure transducer. The slug test data was used to calculate approximate hydraulic conductivity values, which were converted into approximate well yield values using TCEQ Regulatory Guidance document RG-366/TRRP-8 (TCEQ, 2003). In addition to the TCEQ guidance, the methodology for slug testing presented in Butler, et al. (1996) was consulted for designing, conducting, and evaluating the tests. The data were plotted using AQTESOLV^{TM} software.

The tests were conducted to determine if the aquifer production rate was above or below 150 gallons per day (gpd)(570 L/day), which is the regulatory boundary between Class 2 and Class 3 aquifers in Texas (TCEQ, 2003).

3.2.5 Design of Control System

A building inspection was performed by Doug Kladder of Colorado Vintage Companies (CVC). The concrete slab was checked for subterranean beams or other barriers to gas flow via a sound check using a rubber mallet. Holes were drilled through the slab at various locations and the differential pressure between the building and the soil was measured using an Infiltec DMI model digital micromanometer (http://www.infiltec.com). To determine the gas permeability of the sub-slab fill material, a vacuum was applied at a central hole and the pressure differential was measured at various lateral distances.

3.3 Sampling Procedures

The sampling methods used in this study are summarized in Table 3-3. Field data sheets for the roundwater sampling for off-site analysis are given as Appendix B. Field data sheets for soil-gas sampling for both on-site and off-site analysis are given as Appendix C. Sub-slab and indoor air sampling locations are shown in Figure 3-4.

3.3.1 Sample Collection for On-Site Analyses

Groundwater, soil, and shallow soil-gas samples were collected for on-site analyses and used to characterize the subsurface contamination at the site.

Groundwater

One-inch (2.5 cm) PVC was driven to depth and groundwater recovered by applying suction to ¼ in. (0.64 cm) polyethylene tubing. All groundwater samples were unfiltered, grab samples.

Soil Samples

Soil samples were collected with 2 in. by 3 ft (0.05 by 0.9m) split spoon samplers lined with clear acetate. Soil cores were visually examined and screened using a portable photo-ionization detector (PID). The meters were calibrated daily according to manufacturer's instructions. All soil samples were grab samples of approximately 5g collected from cores at discrete depths using disposable EnCore samplers and placed in laboratory-supplied vials. Sampling was intentionally biased towards soils with relatively high levels of VOCs based on visual observation and the PID measurements.

Table 3-3. Summary of Sampling Methods

Analysis Location	Medium	Sampling Method
On-Site	Groundwater	Direct Push / Grab
	Soil	Direct Push / Grab
	Soil-Gas	Direct Push /Sorbent Trap
Off-Site	Groundwater	Low flow / Micropurge
	Soil	Direct Push / Grab
	Sub-Slab and Shallow Soil-Gas	Canister
	Indoor and Ambient Air	Canister

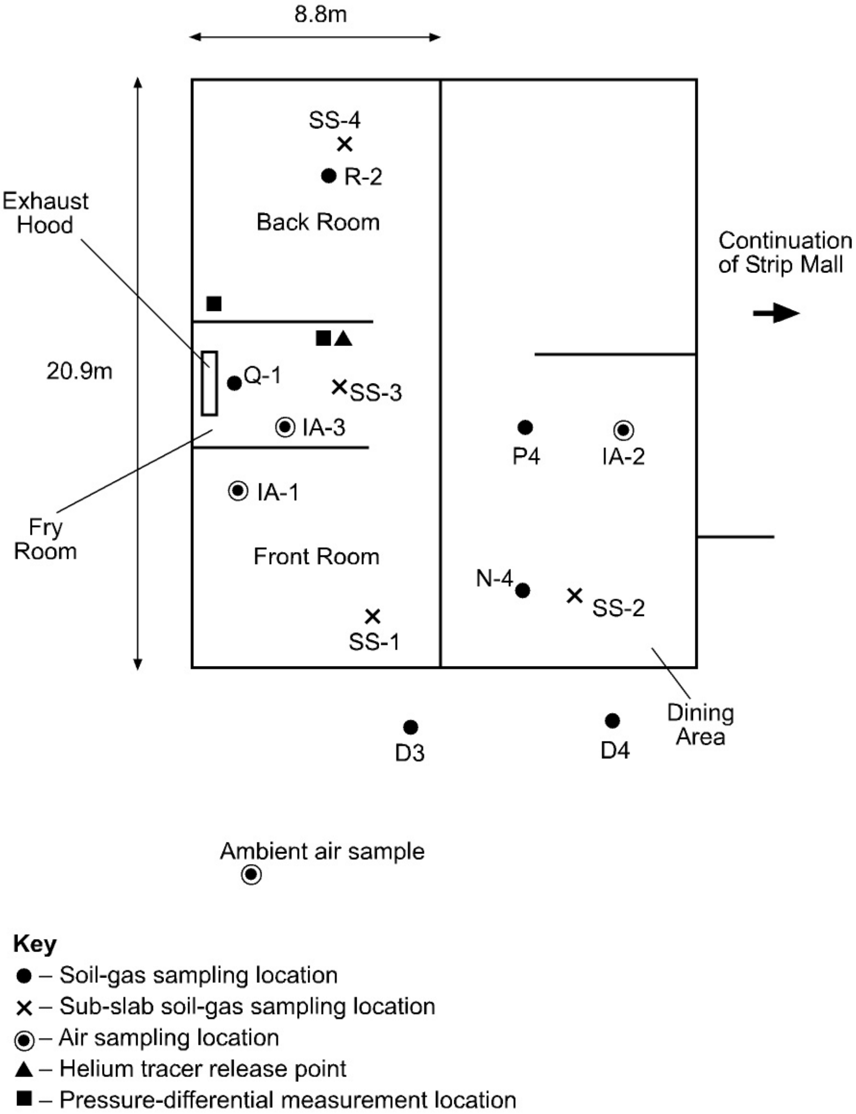

Figure 3-4. Sub-Slab and Indoor Air Sampling Locations

Soil Gas

Soil-gas samples were collected at a depth of five ft (1.5m) below ground surface [bgs] using Geoprobe Post Run Tubing (PRT). The probe was driven to the desired depth and the rod pulled back from the disposable drive tip. A ten ft (3m) length of ¼ in. (0.64 cm) polyethylene tubing was fed down the middle of the rod and turned counter-clockwise until the PRT adapter screwed into the point holder. The probes were left in place for a minimum of 30 minutes and the lines purged of three void volumes before the start of sample collection. The soil-gas samples generally were collected by drawing sample air through a sorbent tube for 15 minutes at a flow rate of 1.0 L/min.

Rotometers were used to control the flow rate of sample air during collection of soil-gas samples using sorbent tubes. The multipoint calibrations of the rotometers using NIST-traceable flow devices were completed at the URS Austin laboratory, prior to deployment to the field. Using these calibration data, sample flows were calculated.

Soil gas sampling was attempted at 24 locations, but samples were obtained at only 10 of these locations. The remaining 14 locations had high resistance to soil-gas flow and no sample could be obtained. Sample collection was not attempted at locations where there was no detectable reduction in pressure over a 15-minute period after inducing a vacuum of 15 in. (38 cm) Hg.

3.3.2 Sample Collection for Off-Site Analyses

Groundwater, soil, shallow soil-gas samples, indoor air, and ambient air samples were collected for off-site analyses. The canister samples collected during the first sampling event are summarized in Table 3-4. All canister samples were two-hour time-integrated samples collected in 6-L evacuated, stainless-steel canisters.

Groundwater

Samples were collected from the 10 permanent groundwater monitoring wells at the site. The two new wells were developed prior to sampling. Wells were purged and groundwater samples were collected from each well using a 12V submersible pump and the low-flow sampling (micropurge) technique. Water quality parameters collected included temperature, pH, specific conductivity, turbidity, oxidation-reduction potential, and dissolved oxygen. Stabilization of all water quality parameters was achieved and documented prior to sample collection. During sample collection, groundwater was pumped directly into pre-preserved sample containers. Field personnel donned a new pair of disposable nitrile gloves prior to collecting each sample. Immediately following sample collection, sample containers were stored on ice in coolers. All sample containers were repacked on fresh ice prior to being shipped.

Pumps and tubing were decontaminated in a plastic tub filled with a mixture of Liquinox soap and water, and rinsed in a plastic tub of clean water. The pump was operated within each tub to ensure the circulation of soap and water inside of the pump housing and tubing during the cleaning process.

Soil Samples

Extracts from three soil samples analyzed on-site were sent off-site for confirmatory analysis. Extracts were used rather than soil to minimize the variability in the starting material used by analysts at each location.

Soil Gas

Soil-gas samples were collected at two depths. Shallow soil-gas samples were collected at six locations at a depth of 5 ft (1.5m) below the ground surface (bgs): four locations inside the building and two locations just outside the building. At the inside locations, sub-slab soil-gas samples also were collected by drilling through the floor and collecting soil gas from immediately beneath the concrete slab.

The shallow soil-gas samples were collected using the Geoprobe Post Run Tubing (PRT) system described above. Canister samples were collected after the collection of sorbent tube samples.

The sub-slab soil-gas probes consisted of a ¼ in. (0.64 cm) swagelok union connected to a 4 in. (10 cm) length of stainless steel tubing that extended to near the bottom of the slab A 2 in. (5 cm) deep starter hole was drilled using a hammer drill and a 7/8 in. (2.2 cm) bit. The hole was continued down through the slab using a 5/16 in. (0.79 cm) bit. The probes were sealed using quick-dry, expanding cement. The probes were left in place for a minimum of 30 minutes and lines purged of three void volumes before the start of sample collection. A 2 ft (0.6m) length polyethylene of tubing was used to connect the canister to the sub-slab probe.

Table 3-4. Canister Samples for Off-Site Analysis During April Sampling Event

Type	Locations	Comments
Indoor Air	2	2-hr integrated samples collected at breathing zone height
Sub-Slab Soil-Gas	4	Samples collected from immediately beneath the building slab
Soil-Gas	4	Samples collected from 5 ft (1.5m) depth near sub-slab sampling locations
Ambient Air	1	For comparison with indoor air results

Differential pressure measurements were made at each soil-gas sampling location using a Dwyer magnehelic gauge (http://www.dwyer-inst.com) capable of reading to the nearest 0.005 in. H_2O (1 Pa).[3]

Indoor Air

Two rounds of indoor air samples were collected: the first round in April 2005 and the second in August 2005. During the April sampling event, samples were collected at two locations: one location within the former dry cleaner business and one location within the adjacent "dining room" area that is connected to the former dry cleaner business (see Figures 2-3 and 2-4). Samples were collected at breathing zone height: four to five ft (1.2 to 1.5m) above floor level. The building HVAC system was not in use, nor had it been used in the days before sampling. External building doors were kept closed during sampling; the building has no windows that can be opened. An ambient air sample was collected just outside the building, concurrent with the indoor air samples.

During the August sampling event, indoor air was collected at breathing zone height within the middle section of the restaurant (i.e., "fry room"). The building HVAC system was operational and in use at that time. External building doors were kept closed during sampling.

Tracer gas tests were performed in conjunction with the second round of indoor air sampling. Pure sulfur hexafluoride (SF_6) was introduced into the sub-slab at a rate of 0.0025 L/min for about 24 hours prior to sampling to verify that vapor intrusion was occurring. No attempt was made to measure the average sub-slab concentration of SF_6. Pure helium was released within the building at a rate of 3 L/min for about 24 hours prior to sampling to measure the air exchange rate for the building. During the tracer tests, air mixing within the building space was enhanced using two box fans. Rotometers were used during the August sampling event to control the rate of tracer gas releases. The multipoint calibrations of the rotometers using NIST-traceable flow devices were completed at the URS Austin laboratory, prior to deployment to the field. Using these calibration data, gas flows were calculated.

A grab sample was collected prior to the release of any tracer gases to document the background levels of SF_6 and He within the building. A two-hour time-integrated indoor air sample was collected approximately 24 hours after the tracer releases were started. Three additional grab samples were collected at hourly intervals after the time-integrated sample was collected to look at short-term temporal variability.

3.4 Analytical Procedures

The analytical methods used in this study are summarized in Table 3-5. During the first phase of work, groundwater, soil, and soil-gas samples were analyzed on-site using EPA Method 8265, direct sampling ion trap mass spectrometry (DSITMS)(US EPA, 2002). The on-site analyses were performed by Dr. William Davis of Tri-Corders (http://www.tri-corders.com/).

Groundwater, confirmatory soil samples, and waste samples were analyzed for VOCs by SW-846 Method 8260 at Kemron's analytical laboratory in Marietta, Ohio. In addition, groundwater samples were analyzed by Kemron for monitored natural attenuation (MNA) parameters: chloride, nitrate, sulfate, ferrous ion, and methane, ethane, and ethene. Field personnel measured dissolved oxygen, redox potential, etc. of groundwater samples in the field using an YSI 55 MPS instrument or equivalent.

Soil gas and air samples were analyzed off-site at Air Toxics Ltd's analytical laboratory in Folsom, CA. VOCs were determined by US EPA Method TO-15 (US EPA, 1999). Soil-gas samples were analyzed in full-scan mode. The indoor air and ambient air samples were analyzed by Selective Ion Mode (SIM) to achieve better analytical sensitivity. The primary compound of interest was PCE, which is a widely-used dry cleaning solvent. The common degradation products of PCE also were included as target analytes: TCE, DCE, and VC.

Helium was analyzed by ASTM Method D-1946; the reporting limit was approximately 0.01%. SF_6 was analyzed by gas chromatography with an electron capture detector (GC-ECD). The reporting limit for SF_6 was approximately 0.2 ppbv.

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[3] One atmosphere (atm) = 1013 millibars (mbar) = 101,300 Pascals (Pa) = 29.9 inches of mercury (in. Hg) = 1033 centimeters of water (cm H_2O) = 760 Torr. One Pa = 10 g/cm-sec^2 = 0.010 cm H_2O = 0.0040 in. H_2O.

3.5 Sample Handling and Chain of Custody Procedures

Similar handling procedures were employed for both the liquid and indoor air samples. Upon completion of the collection of each field sample, the samples were labeled with the following information:

- ID number;
- Project name
- Sampling location;
- Sampler; and
- Date & time of sample collection.

The samples were logged into a field notebook. At the end of the sampling effort, the samples were packed and shipped to the off-site analytical laboratory. All samples submitted to the laboratory were documented on a chain-of-custody form that accompanied the shipment of samples from the field to the lab. The samples and other field documentation records were shipped by FedEx overnight service.

Groundwater and Soil Extract Samples

Sample containers were completely filled with minimal air-filled headspace. Samples were stored and shipped at approximately 4°C.

Air Samples

Canister pressures were checked in the field prior to sampling. Post-sampling pressures also were checked. Canister samples do not require refrigeration or any special handling techniques during shipping, but the canister valves must be securely closed (finger-tight only), Swagelok plugs firmly attached, and the canisters packed in shipping crates provided by the laboratory.

Sample identification for canister samples followed this general protocol:

GP-IAX-MMDDYY-R-001

Where:
GP = identifies the project as the Grand Plaza site;
XXX = identifies the sampling location (e.g., IA-1);
MMDDYY = Month, Day, Year;
R = Sample type—R for routine; and
001 = Sequential sample number.

Table 3-5. Summary of Sampling and Analytical Methods for VOCs

Medium	Analysis Location	Analyte	Analytical Method
Groundwater	On-Site	VOCs	EPA Method 8265 (DSITMS)
	Off-Site	VOCs	EPA Method 8260
		Chloride	SW846 Method 9056
		Nitrate	SW846 Method 9056
		Sulfate	SW846 Method 9056
		Ferrous Ion	SM3500
		Methane, Ethane, Ethene	RSK175
Soil	On-Site	VOCs	EPA Method 8265
	Off-Site	VOCs	EPA Method 8260
Soil-Gas	On-Site	VOCs	EPA Method 8265
	Off-Site	VOCs	EPA TO-15 full-scan
Air	Off-Site	VOCs	EPA TO-15 SIMs
		SF_6 (Tracer Gas)	GC-ECD
		Helium (Tracer Gas)	ASTM D-1946

SECTION 4
RESULTS

The on-site analytical data for the site characterization effort are presented below, followed by the data for the groundwater sampling, the slug tests, and the vapor intrusion study. A summary of results for the health & safety and waste characterization & disposal efforts also is given.

4.1 On-Site Analytical Results for Site Characterization

4.1.1 Groundwater

The results of the on-site analysis of groundwater samples are shown in Table 4-1 (all tables are given at the end of the section). The applicable State standards are included in the table for comparison purposes. Groundwater samples were collected at 28 locations. Five samples were collected from within the building, four of which were collected adjacent to soil boring (“SB”) locations from a previous investigation. Twenty-three samples were collected from the sampling array outside the building. Sample collection was attempted at five additional locations where bedrock was relatively shallow, but no groundwater could be obtained at these locations. The depth to bedrock was measured at all 33 locations where probes were pushed and at the eight existing monitoring wells. The depth to bedrock is plotted in Figure 4-1.

4.1.2 Soil

The results of the on-site analysis of soil samples are shown in Table 4-2. The applicable State standards are included in the table for comparison purposes. A total of 77 samples were collected from 15 locations within or very near the building. Fifty-seven samples were collected from 11 locations within the building and 20 samples were collected from four locations outside the building. The results are shown in Table 4-2. The samples marked “SB” were collected at the four locations where soil borings were collected during previous studies at the site. A cross-section of the site showing sub-surface geological features is shown in Figure 4-2.

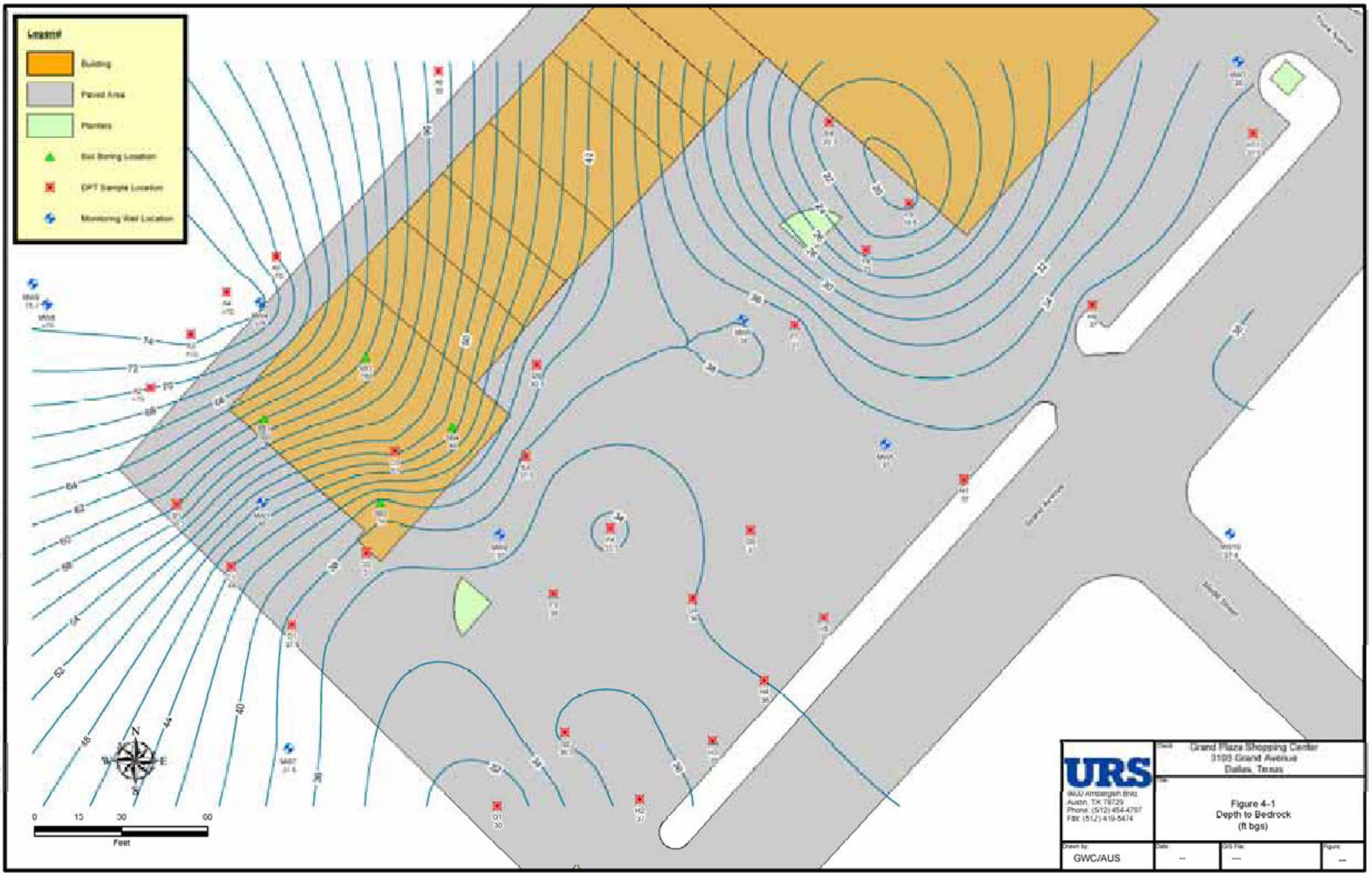
4.1.3 On-Site Soil Gas

The results of the on-site analysis of soil-gas samples are shown in Table 4-3. Sampling was attempted at 24 locations, but samples were obtained at only 10 of these locations. The remaining 14 locations had high resistance to soil-gas flow and no sample could be obtained. Presumably, this was due to the clayey nature of the surface soils. In addition to the soil-gas samples at 5 ft (1.5m) depth, soil-gas samples were collected at the four sub-slab soil-gas sampling locations. These data also are shown in Table 4-3.

4.2 Results of Off-Site Analysis of Groundwater

Groundwater samples were collected from nine of the ten wells on October 20–21, 2005. No sample could be obtained from MW–2 due to insufficient water volume within the well. The samples were analyzed off-site by EPA Method 8260 for a list of 66 target compounds. The full analytical reports for the October VOC groundwater samples are given in Appendix D. Eight VOCs were detected in one or more of the samples; these results are summarized in Table 4-4. The applicable State standards are included in the table for comparison purposes.

Samples were collected again for VOCs from three of the groundwater monitoring wells on December 13–14, 2005. The full analytical reports for the December VOC groundwater samples are given in Appendix E. Eleven VOCs were detected in one or more of the samples; these results are summarized in Table 4-5.

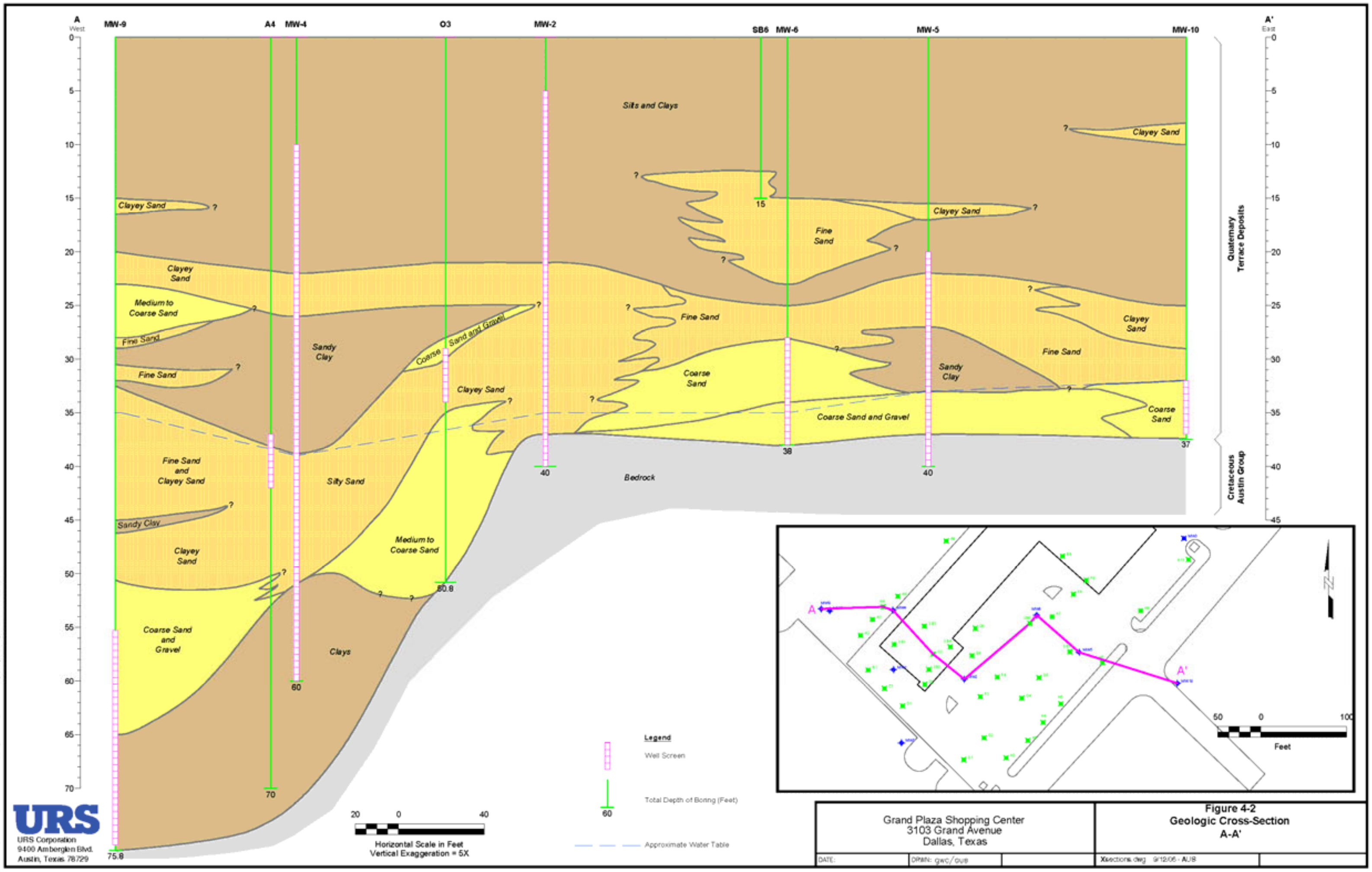


URS
9800 Amberglen Blvd.
Austin, TX 78729
Phone: (512) 454-4797
Fax: (512) 419-5474

Grand Plaza Shopping Center
3105 Grand Avenue
Dallas, Texas

Figure 4-1
Depth to Bedrock
(ft bgs)

Drawn by: GWC/AUS
Date: --
GIS File: ---
Figure: --



Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas

Figure 4-2
Geologic Cross-Section
A-A'

DATE:	DRWN: gwc/aus		Xsections.dwg 9/12/06 - AUS	

The groundwater was monitored in the field for pH, conductivity, and various other parameters. These results are given in Table 4-6. The groundwater samples collected in October also were analyzed for monitored natural attenuation (MNA) parameters. The MNA results are given in Appendix D and summarized in Table 4-7.

The groundwater sample collected in October from MW–9 was analyzed for various elements and for semi-volatile organic compounds (SVOCs). These results are given in Appendix D and summarized in Table 4-8.

4.3 Results of Slug Tests

Tests were performed at three wells (MW–7, MW–9, and MW–10) to estimate hydraulic conductivity. The results are given in Appendix F.

4.4 Evaluation of Vapor Intrusion

4.4.1 Off-Site Analysis of Soil-Gas

Shallow soil-gas samples were collected from a depth of 5 ft (1.5m) bgs at six locations: two locations just outside the building and four locations beneath the building. Sub-slab soil-gas samples were collected at three locations. Sampling was attempted at a fourth sub-slab location (SS1), but no sample could be obtained. A duplicate sample (i.e., sequential duplicate) was collected at location SS3.

The results for selected compounds are shown in Table 4-9. The full analytical reports for the off-site analysis of soil-gas samples are given as Appendix G. Each sub-slab sample was collected in close proximity to a shallow soil-gas sample. The comparison of the shallow and sub-slab soil-gas data is shown in Table 4-10.

4.4.2 Off-Site Analysis of Indoor and Ambient Air Samples

Two indoor air samples and one outdoor ambient air sample were collected during April 2005. The full analytical reports for the off-site analysis of these air samples are given as Appendix H. The results for these samples are summarized in Table 4-11. Additional indoor air samples were collected during August 2005 to further evaluate vapor intrusion. The full analytical reports for the off-site analysis of these air samples are given as Appendix I. The results for these samples are summarized in Tables 4-12 and 4-13. Sample GP-101 was collected prior to the release of any tracer gas to determine the background levels of the tracer gases in the indoor air. The remaining samples were collected after the tracer gases had been continuously released for the previous 24 hours.

4.4.3 Design of Control System

The site inspection report from the design engineer is given as Appendix J. The specifications for the control system are given in Section 6.0.

4.5 Health & Safety

There were no OSHA recordable injuries for this project. There were no reports of near misses or minor injuries requiring First Aid. There were no incidents where drilling breached underground utility lines.

4.6 Waste Disposal

Samples of waste liquid and soil were collected by URS personnel and analyzed by the same off-site laboratory that analyzed groundwater and soil samples. All materials were found to be non-hazardous. Wastes were transported and disposed of by Environmental Industries, LP of Plano, Texas.

4.7 Results of Quality Control (QC) Checks

Duplicate groundwater samples from seven locations were analyzed on-site. These results are shown in Table 4-14.

Duplicate soil samples for two depths at one location were analyzed on-site. These results are shown in Table 4-15. Aliquots of the water extracts for three soil samples were analyzed by the off-site laboratory for confirmatory purposes. The full analytical report for these analyses is included as Appendix K. The comparison of the on-site and off-site analytical results is shown in Table 4-16.

Soil gas samples from seven locations were analyzed both on-site and off-site. The comparison of the analytical results for PCE is shown in Table 4-17.

The results for QC samples for the groundwater sampling are given in Tables 4-18 and 4-19. The full analytical reports for these samples may be found in Appendices D and E.

Table 4-1. Results of On-Site Analysis of Groundwater Samples

Sampling Location	Concentration (µg/L)					
	PCE	**TCE**	**DCE**	**Vinyl Chloride**	**Benzene**	**Toluene**
Sampling Array Outside the Building						
A2	1.4	<3.9	3.9	<2	<2.7	<3.1
A3	7.5	1.4	4.2	<4	<2.7	<3.6
A4	62	12	85.3	<4	<2.7	<3.6
A5	<5.4	<3.9	<2	<2	<2.7	<3.1
A9	<5.4	<3.9	<2	<2	<2.7	<3.1
B1	<2.9	<1.5	<4.4	<4.4	<3.1	<3.1
C2	89.5	32.7	146	<4	<2.7	<3.6
D1	<2.9	<1.5	<4.4	<4.4	<3.1	<3.1
D2	67.2	13	30.6	<4	<2.7	<3.6
D5	<2.8	<2.9	<3.9	<4	<2.7	<3.6
E4	135	19.3	87.2	<4.4	<3.1	<3.1
F3	40	0.8	3.6	<4.4	<3.1	<3.1
F7	<5.4	<3.9	<2	<2	<2.7	<3.1
G2	2.9	<2.9	<3.9	<4	<2.7	<3.6
G4	15.3	<1.5	<4.4	<4.4	<3.1	<3.1
G5	68.3	7.6	40.2	<4.4	<3.1	<3.1
H2	<5.4	<3.9	<2	<2	<2.7	<3.1
H3	37.9	4	15.1	<4	<2.7	<3.6
H4	2	<1.5	<4.4	<4.4	<3.1	<3.1
H5	2.8	<3.9	3.2	<2	<2.7	<3.1
H7	<2.8	<2.9	<3.9	<4	<2.7	<3.6
H9	9.9	1.6	7.3	<2	<2.7	<3.1
H11	1.1	1	<3.9	<4	<2.7	<3.6
Additional Locations Within Building						
O3	155	37.6	364	<4.4	<3.1	<3.1
SB01	8.9	2.9	124	<2	<2.7	<3.1
SB02	15.8	5.3	176	<2	<2.7	<3.1
SB03	130	21.7	119	<2	<2.7	<3.1
SB04	15.3	1	19.2	<4	<2.7	<3.6
Regulatory Standards[a]						
TCEQ PCLs	550,000	270,000	14,000,000 (cis)	6,100	85,000	11,000,000

[a] Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) for the inhalation pathway at a 0.5-acre source area, commercial setting ($^{Air}GW_{inh\text{-}v}$).

Table 4-2. Results of On-Site Analysis of Soil Samples

Sampling Location	Concentration (µg/Kg)					
	PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
Sampling Array Outside the Building						
B2 – 1 ft	<10.8	<11.2	<14.7	<15.2	<10.4	<13.7
B2 – 5 ft	<10.8	<11.2	<14.7	<15.2	<10.4	<13.7
B2 – 10 ft	29.9	<11.2	<14.7	<15.2	<10.4	<13.7
B2 – 15 ft	37.4	5.5	<14.7	<15.2	<10.4	<13.7
B2 – 20 ft	14.5	<11.2	<14.7	<15.2	<10.4	<13.7
D2 – 1 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
D2 – 5 ft	0.0	6.7	81.7	<17.9	<12.4	<12.6
D2 – 10 ft	95.9	22.9	45.8	<17.9	<12.4	<12.6
D2 – 15 ft	122	10.8	50.2	<17.9	<12.4	<12.6
D2 – 20 ft	102	<6.2	<17.6	<17.9	<12.4	<12.6
D3 – 5 ft	<10.8	<11.2	130	<15.2	<10.4	<13.7
D3 – 10 ft	10.7	34.4	52.3	<15.2	<10.4	<13.7
D3 – 15 ft	316	52.8	0.0	<15.2	<10.4	<13.7
D3 – 17 ft	14.4	0.0	0.0	<15.2	<10.4	<13.7
D3 – 20 ft	160	14.9	45.3	<15.2	<10.4	<13.7
D4 – 1 ft	<10.8	<11.2	<14.7	<15.2	<10.4	<13.7
D4 – 5 ft	<10.8	<11.2	<14.7	<15.2	<10.4	<13.7
D4 – 10 ft	170	15.6	<14.7	<15.2	<10.4	<13.7
D4 – 15 ft	46.7	22.8	<14.7	<15.2	<10.4	<13.7
D4 – 20 ft	88.1	7.6	<14.7	<15.2	<10.4	<13.7

Table 4-2. Results of On-Site Analysis of Soil Samples (continued)

Sampling Location	Concentration (μg/Kg)					
	PCE	**TCE**	**DCE**	**Vinyl Chloride**	**Benzene**	**Toluene**
Sampling Locations Within the Building						
M3 – 6 ft	18.6	<6.2	155	<17.9	<12.4	<12.6
M3 – 10 ft	122	<6.2	261	<17.9	<12.4	<12.6
M3 – 13 ft	164	2.0	223	<17.9	<12.4	<12.6
N2 – 1 ft	3,440	249	2,670	<17.9	<12.4	<12.6
N2 – 4 ft	878	77.4	6,390	<17.9	<12.4	<12.6
N2 – 9 ft	1,200	263	2,090	<17.9	<12.4	<12.6
N2 – 12 ft	1,290	220	1,630	<17.9	<12.4	<12.6
N2 – 16 ft	603	62.3	654	<17.9	<12.4	<12.6
N2 – 23 ft	461	28.9	429	<17.9	<12.4	<12.6
N2 – 28 ft	522	40.7	449	<17.9	<12.4	<12.6
N6 - 0.5 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
N6 – 3 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
N6 – 6 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
N6 – 13 ft	52.0	<6.2	18.3	<17.9	<12.4	<12.6
O3 - 0.5 ft	1,770	100	<14.7	<15.2	<10.4	<13.7
O3 - 3.5 ft	<10.8	<11.2	275	<15.2	<10.4	<13.7
O3 – 7 ft	140	102	818	<15.2	<10.4	<13.7
O3 – 10 ft	291	70.6	509	<15.2	<10.4	<13.7
O3 – 16 ft	204	32.4	285	<15.2	<10.4	<13.7
O3 – 21 ft	342	38.5	318	<15.2	<10.4	<13.7
O3 - 27.5 ft	114	16.4	161	<15.2	<10.4	<13.7
O3 - 33.5 ft	130	18.6	190	<15.2	<10.4	<13.7
O3 – 38 ft	51.6	<11.2	26.9	<15.2	<10.4	<13.7

Table 4-2. Results of On-Site Analysis of Soil Samples (continued)

Sampling Location	Concentration (µg/Kg)					
	PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
Sampling Locations Within the Building (contd.)						
P1 - 0.5 ft	1,540	190	<17.6	<17.9	<12.4	<12.6
P1 – 1 ft	69.4	10.2	269	<17.9	<12.4	<12.6
P1 – 4 ft	219	30.2	250	<17.9	<12.4	<12.6
P1 - 7.5 ft	511	68.0	499	<17.9	<12.4	<12.6
P1 - 10.5 ft	543	60.6	524	<17.9	<12.4	<12.6
P4 - 0.5 ft	387	24.3	146	<15.2	<10.4	<13.7
P4 - 1.2 ft	90.0	19.5	39.4	<15.2	<10.4	<13.7
P4 – 6 ft	38.1	<11.2	<14.7	<15.2	<10.4	<13.7
P4 - 12.5 ft	129	18.2	99.9	<15.2	<10.4	<13.7
P4 - 17.5 ft	174	23.0	177	<15.2	<10.4	<13.7
P4 - 20.5 ft	126	14.2	119	<15.2	<10.4	<13.7
Q1 – 3 ft	1,100	2,320	1,340	<17.9	<12.4	<12.6
Q1 – 9 ft	785	513	899	<17.9	<12.4	<12.6
Q1 - 12.5 ft	500	206	659	<17.9	<12.4	<12.6
Q1 - 18.5 ft	336	73.3	313	<17.9	<12.4	<12.6
Q1 – 22 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
Q1 – 25 ft	90.2	<6.2	59.6	<17.9	<12.4	<12.6
Q1 - 27.5 ft	158	3.7	83.7	<17.9	<12.4	<12.6
R1 - 0.5 ft	75.6	<6.2	<17.6	<17.9	<12.4	<12.6
R1 - 3.5 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
R1 - 6.5 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 10 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 15 ft	24.1	<6.2	<17.6	<17.9	<12.4	<12.6

Table 4-2. Results of On-Site Analysis of Soil Samples (continued)

Sampling Location	Concentration (µg/Kg)					
	PCE	**TCE**	**DCE**	**Vinyl Chloride**	**Benzene**	**Toluene**
Sampling Locations Within the Building (contd.)						
R2 - 0.5 ft	870	134	<14.7	<15.2	<10.4	<13.7
R2 – 3 ft	<10.8	<11.2	<14.7	<15.2	<10.4	<13.7
R2 – 9 ft	37.7	<11.2	63.7	<15.2	<10.4	<13.7
R2 - 15.5 ft	255	33.8	142	<15.2	<10.4	<13.7
R2 - 20.5 ft	51.8	9.6	44.1	<15.2	<10.4	<13.7
R2 - 22.5 ft	39.2	6.5	28.6	<15.2	<10.4	<13.7
R5 – 1 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
R5 – 6 ft	17.7	9.5	13.0	<17.9	<12.4	<12.6
SB3 – 3 ft	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
SB3 – 6 ft	58.1	3.5	19.5	<17.9	<12.4	<12.6
SB3 – 10 ft	71.9	6.6	26.7	<17.9	<12.4	<12.6
Regulatory Standards[a]						
TCEQ PCLs	1,000,000	350,000	17,000,000	68,000	77,000	110,000,000

[a] Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) for the inhalation pathway at a 0.5-acre source area, commercial setting ($^{Air}Soil_{inh-v}$).

Table 4-3. Results of On-Site Analysis of Soil-Gas Samples

Sampling Location	Concentration (ppbv)					
	PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
Soil-Gas Samples at 5 ft bgs[a]						
C-2	<0.3	<0.4	<0.5	<0.8	<0.6	<0.5
D-3	<0.4	<0.6	<0.8	<1	<0.9	<0.8
D-4	<0.2	<0.2	<0.2	<0.4	<0.3	<0.3
D-8	<0.3	<0.4	<0.5	<0.8	<0.6	<0.5
M-3	11	<0.6	<0.8	<1	<0.9	<0.8
P-4	3.8	<0.4	<0.5	<0.8	<0.6	<0.5
Q-1	60	<0.4	<0.5	<0.8	<0.6	<0.5
R-1	<1	<1	<2	<3	<2	<2
R-2	160	<0.4	<0.5	<0.8	<0.6	<0.5
Sub-Slab Soil-Gas Samples[b]						
SS-1	3,700	<0.6	<0.8	<1	<0.9	<0.8
SS-1B[c]	4,200	<0.4	<0.5	<0.8	<0.6	<0.5
SS-3	140	<0.4	<0.5	<0.8	<0.6	<0.5
SS-3 dup	120	<0.4	<0.5	<0.8	<0.6	<0.5
SS-3 dup	88	<0.4	<0.5	<0.8	<0.6	<0.5
SS-3 dup	100	<0.4	<0.5	<0.8	<0.6	<0.5
SS-4	35	<0.2	<0.2	<0.4	<0.3	<0.3

[a] No sample was obtained at the following locations due to high vacuum/no flow in the sampling system: B2, D2, D5, D6, E8, F3, H8, M1, N4, N6, O3, P6, Q3, and R5.

[b] No sample was obtained at location SS-2 due to high vacuum/no flow in the sampling system.

[c] Location SS-1B was 2 ft from location SS-1

Table 4-4. Results of Off-Site Analysis of Groundwater Samples Collected in October 2005

Sampling Location	Measured Concentration (μg/L)							
	PCE	TCE	Cis-1,2-DCE	Trans-1,2-DCE	Chloroform	Methylene Chloride	1,4-DCB	Freon 11
MW–1	184	22.2	140	ND	0.95	ND	ND	ND
MW–2	--	--	--	--	--	--	--	--
MW–3	4.64	2.16	1.29	ND	ND	ND	0.374	ND
MW–4	105	11.5	59.0	0.511	1.20	ND	0.357	0.828
MW–5	25.4	3.61	1.51	ND	0.738	ND	0.457	0.877
MW–6	83.3	25.0	45.7	0.54	0.267	ND	0.229	0.385
MW–7	9.57	1.77	0.271	ND	0.889	ND	0.318	1.03
MW–8	12.8	1.80	0.588	ND	1.20	ND	0.487	0.626
MW–9	1.15	4.42	0.344	ND	0.501	0.367	0.659	12.5
MW–10	16.0	4.49	2.81	ND	0.505	ND	0.224	0.511
Regulatory Standards[a]								
TCEQ PCLs	550,000	270,000	23,000,000	14,000,000	33,000	2,100,000	37,000,000	5,700,000

DCB = Dichlorobenzene

DCE = Dichloroethylene

ND = Not Detected

[a] Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) for the inhalation pathway at a 0.5-acre source area, commercial setting ($^{Air}GW_{inh-v}$).

Table 4-5. Results of Off-Site Analysis of Groundwater Samples Collected in December 2005

Sampling Location	Measured Concentration (µg/L)							
	PCE	TCE	Cis-1,2-DCE	Trans-1,2-DCE	Chloroform	Methylene Chloride	1,4-DCB	Freon 11
MW–2	408	60.3	133	1.04	0.939	ND	0.442	0.389
MW–9	0.513	3.99	0.421	ND	0.433	ND	0.158	8.62
MW–10	21.9	5.18	3.11	ND	0.524	ND	ND	0.412
Regulatory Standards[1]								
TCEQ PCLs	550,000	270,000	23,000,000	14,000,000	33,000	2,100,000	37,000,000	5,700,000

Sampling Location	Measured Concentration (µg/L)			
	Benzene	Toluene	1,2-DCA	Acetone
MW–2	0.181	0.329	ND	8.48
MW–9	ND	ND	0.370	ND
MW–10	ND	ND	ND	ND
Regulatory Standards[a]				
TCEQ PCLs	85,000	110,000,000	55,000	350,000,000

DCA = Dichloroethane

DCB = Dichlorobenzene

DCE = Dichloroethylene

ND = Not Detected

a Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) for the inhalation pathway at a 0.5-acre source area, commercial setting ($^{Air}GW_{inh\text{-}v}$).

Table 4-6. Results of On-Site Monitoring of Groundwater Samples Collected in October 2005

Sampling Location	Last Reading in Series Take at Each Well						
	pH	Temperature (°C)	Conductivity (µS/cm)	Dissolved O_2 (mg/L)	ORP (mV)	TDS (g/L)	Depth to Water (ft)
MW–1	6.9	24	12	1.0	47	7.7	28.9
MW–2	--	--	--	--	--	--	--
MW–3	7.0	26	11	0.3	149	7.3	31.7
MW–4	6.9	22	12	0.7	52	7.6	29.2
MW–5	6.9	26	12	0.6	160	7.7	33.1
MW–6	7.0	24	11	0.2	-138	7.0	33.9
MW–7	6.9	25	11	2.1	75	7.3	32.2
MW–8	6.9	22	12	0.5	77	7.5	30.6
MW–9	7.2	22	10	0.2	-83	6.4	31.0
MW–10	7.0	25	11	0.3	-149	7.5	33.7

O_2 = Oxygen

ORP = Oxidation reduction potential

TDS = Total dissolved solids

Table 4-7. Results of Off-Site Monitoring of Groundwater Samples for MNA Parameters

Sampling Location	**Chloride (mg/L)**	**Nitrate (mg/L)**	**Sulfate (mg/L)**	**Iron (mg/L)**	**Methane (µg/L)**	**Ethane (µg/L)**	**Ethene (µg/L)**
MW–1	50.5	5.46	103	0.0273	1.22	<0.25	<0.25
MW–2	--	--	--	--	--	--	--
MW–3	44.9	3.02	94.6	0.205	159	<0.25	0.519
MW–4	50.8	5.28	104	0.0434	0.482	<0.25	<0.25
MW–5	45.3	5.30	105	0.0365	396	<0.25	1.94
MW–6	47.2	1.40	90.4	0.194	89.4	<0.25	0.492
MW–7	51.4	5.73	98.6	0.04	0.707	<0.25	<0.25
MW–8	52.2	5.06	103	<0.02	0.458	<0.25	<0.25
MW–9	49.3	3.10	60.8	3.10	70.4	<0.25	1.90
MW–10	50.5	3.89	95.5	0.071	19.8	<0.25	<0.25

Table 4-8. Results of Off-Site Monitoring of MW-9 Sample for Selected Parameters

Analyte	**MW-9 Result (mg/L)**	**U.S. EPA MCL (mg/L)**	**Comment**
Silver	<0.005	0.10	No EPA MCL. Value shown is secondary standard.
Arsenic	0.0405	0.010	Measured value exceeds the MCL for drinking water
Barium	0.311	2	
Cadmium	<0.0025	0.005	
Chromium	0.0182	0.1	
Copper	0.00522	1.3	
Lead	0.00983	0.015	
Selenium	<0.005	0.05	
Zinc	0.0243	5	No EPA MCL. Value shown is secondary standard.
Mercury	<0.0001	0.002	
SVOCs	ND	--	Non-detect for all 65 target compounds. Typical DL was 2.6 µg/L.

Table 4-9. Results of Off-Site Analysis of Soil-Gas Samples Collected in April 2005

Sampling Location	Concentration (ppbv)					
	PCE	**TCE**	**Cis-1,2-DCE**	**Vinyl Chloride**	**Benzene**	**Toluene**
Shallow Soil-Gas						
D3 – 5 ft	39	27	520	13	<4.5	13
D4 – 5 ft	50	18	45	3.8	3.0	5.5
N4 – 5 ft	<130	<130	29,000	10,000	<130	<130
P4 – 5 ft	180	20	170	69	1.2	4.6
Q1 – 5 ft	780	670	1,400	98	<4.3	<4.3
R2 – 5 ft	710	100	1,200	1,500	<7.8	<7.8
Sub-Slab Soil-Gas						
SS-2	3,900	530	860	<18	<18	<18
SS-3	2,600,000	170,000	340,000	<11,000	<11,000	<11,000
SS-3 dup	2,200,000	140,000	290,000	<9,800	<9,800	<9,800
SS-4	8,600	1,100	310	<41	<41	500

Table 4-10. Comparison of Results for Shallow and Sub-Slab Soil-Gas Samples Collected in April 2005

Sampling Location	Concentration (ppbv)					
	PCE	**TCE**	**Cis-1,2-DCE**	**Vinyl Chloride**	**Benzene**	**Toluene**
N4 – 5 ft	<130	<130	29,000	10,000	<130	<130
SS-2	3,900	530	860	<18	<18	<18
Q1 – 5 ft	780	670	1,400	98	<4.3	<4.3
SS-3	2,600,000	170,000	340,000	<11,000	<11,000	<11,000
R2 – 5 ft	710	100	1,200	1,500	<7.8	<7.8
SS-4	8,600	1,100	310	<41	<41	500

Table 4-11. Results of Off-Site VOC Analysis of Indoor Air and Ambient Air Samples for April 2005

Sampling Location	Concentration (ppbv)					
	PCE	TCE	Cis-1,2-DCE	Vinyl Chloride	Trans-1,2-DCE	1,1-DCE
Indoor – 1 (Restaurant)	13	0.65	1.6	<0.019	<0.019	<0.019
Indoor – 2 (Dining Area)	10	0.52	1.1	<0.018	<0.018	<0.018
Ambient Air	0.11	<0.036	<0.036	<0.018	<0.018	<0.018

Note: All samples were two-hour integrated samples.

Table 4-12. Results of Off-Site VOC Analysis of Indoor Air Samples for August 2005

Sample ID	Concentration (ppbv)					
	PCE	TCE	Cis-1,2-DCE	Vinyl Chloride	Trans-1,2-DCE	1,1-DCE
GP-104	3.7	0.16	0.26	<0.014	<0.014	<0.014
GP-105	16	0.67	1.2	<0.014	<0.014	<0.014
GP-106	14	0.64	1.1	<0.020	<0.020	<0.020

Table 4-13. Results of Off-Site Tracer Gas Analysis of Indoor Air Samples for August 2005

Sample ID	Sampling Date	Sampling Time	Helium (%)	SF_6 (ppbv)
GP-101	Aug 29	0815 – 0816	<0.014	<0.27
GP-102	Aug 30	0829 – 0830	0.057	0.78
GP-103	Aug 30	0827 – 1027	<0.020	0.57
GP-104	Aug 30	1129 – 1130	<0.014	0.55
GP-105	Aug 30	1255 – 1256	0.033	1.3
GP-106	Aug 30	1405 – 1408	0.033	2.4

Table 4-14. Results of On-Site Duplicate Analysis of Groundwater Samples

Sampling Location	Concentration (µg/L)					
	PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
A2	1.4	<3.9	3.9	<2	<2.7	<3.1
A2 Dup	<5.4	<3.9	2.5	<2	<2.7	<3.1
A3	7.5	1.4	4.2	<4	<2.7	<3.6
A3 Dup	7.2	2	4.3	<4	<2.7	<3.6
G5	68.3	7.6	40.2	<4.4	<3.1	<3.1
G5 Dup	81.1	10.7	49.9	<4.4	<3.1	<3.1
H9	9.9	1.6	7.3	<2	<2.7	<3.1
H9 Dup	5.5	<3.9	3.6	<2	<2.7	<3.1
SB01	8.9	2.9	124	<2	<2.7	<3.1
SB01 Dup	7.5	4.2	143	<2	<2.7	<3.1
SB03	130	21.7	119	<2	<2.7	<3.1
SB03 Dup	114	20.5	105	<2	<2.7	<3.1
SB04	15.3	1	19.2	<4	<2.7	<3.6
SB04 Dup	12.3	1.5	18.7	<4	<2.7	<3.6

Table 4-15. Results of On-Site Duplicate Analysis of Soil Samples

Sampling Location	Concentration (μg/Kg)					
	PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
R1 - 0.5 ft	75.6	<6.2	<17.6	<17.9	<12.4	<12.6
R1 - 0.5 ft dup	47.6	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 15 ft	24.1	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 15 ft dup	40.8	<6.2	<17.6	<17.9	<12.4	<12.6

Table 4-16. Comparison of On-Site and Off-Site Analysis of Soil Samples

Sampling Location	Laboratory	Concentration (μg/Kg)					
		PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
SB3 – 10 ft	On-site	71.9	6.6	26.7	<17.9	<12.4	<12.6
SB3 – 10 ft	Off-site	58.8	10.8	13.8	<11	<5	<11
SB3 – 10 ft dup	Off-site	59.5	<11	10.0	<11	<5	<11
	RPD	-22.4%	39.1%	-93.6%			
R5 – 1 ft	On-site	<11.9	<6.2	<17.6	<17.9	<12.4	<12.6
R5 – 1 ft	Off-site	<11	<11	<11	<11	<5	<11
R1 – 0.5 ft	On-site	75.6	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 0.5 ft dup	On-site	47.6	<6.2	<17.6	<17.9	<12.4	<12.6
R1 – 0.5 ft	Off-site	50.6	<11	<11	<11	<5	<11
	RPD	-21.7%					

Table 4-17. Comparison of On-Site and Off-Site Analysis of Soil-Gas Samples

Sampling Location	Laboratory	Concentration (μg/m^3)					
		PCE	TCE	DCE	Vinyl Chloride	Benzene	Toluene
D3 – 5 ft	On-site	<0.4	<0.6	<0.8	<1	<0.9	<0.8
D3 – 5 ft	Off-site	39	27	520	13	<4.5	13
	RPD	NC	NC	NC	NC	NC	NC
D4 – 5 ft	On-site	<0.2	<0.2	<0.2	<0.4	<0.3	<0.3
D4 – 5 ft	Off-site	50	18	45	3.8	3.0	5.5
	RPD	NC	NC	NC	NC	NC	NC
P4 – 5 ft	On-site	3.8	<0.4	<0.5	<0.8	<0.6	<0.5
P4 – 5 ft	Off-site	180	20	170	69	1.2	4.6
	RPD	99%	NC	NC	NC	NC	NC
Q1 – 5 ft	On-site	60	<0.4	<0.5	<0.8	<0.6	<0.5
Q1 – 5 ft	Off-site	780	670	1,400	98	<4.3	<4.3
	RPD	92%	NC	NC	NC	NC	NC
R2 – 5 ft	On-site	160	<0.4	<0.5	<0.8	<0.6	<0.5
R2 – 5 ft	Off-site	710	100	1,200	1,500	<7.8	<7.8
	RPD	77%	NC	NC	NC	NC	NC
SS3 – subslab	On-site	140	<0.4	<0.5	<0.8	<0.6	<0.5
SS3 – subslab	Off-site	2,600,000	170,000	340,000	<11,000	<11,000	<11,000
	RPD	100%	NC	NC	NC	NC	NC
SS4 – subslab	On-site	35	<0.2	<0.2	<0.4	<0.3	<0.3
SS4 – subslab	Off-site	8,600	1,100	310	<41	<41	500
	RPD	100%	NC	NC	NC	NC	NC

NC = Not calculated

Table 4-18. Results of Off-Site VOC Analysis of Groundwater QC Samples

Sampling Location	Measured Concentration (μg/L)							
	PCE	TCE	Cis-1,2-DCE	Trans-1,2-DCE	Chloroform	Methylene Chloride	1,4-DCB	Freon 11
October 2005 Sampling Event								
MW–4	105	11.5	59.0	0.511	1.20	ND	0.357	0.828
MW–4 dup	101	10.9	55.7	0.415	1.19	ND	0.358	0.868
Trip Blank	ND	ND	ND	ND	ND	ND	ND	ND
Equipment Blank[a]	0.68	0.292	ND	ND	ND	ND	ND	ND
December 2005 Sampling Event								
MW–9[b]	0.513	3.99	0.421	ND	0.433	ND	0.158	8.62
MW–9 dup[b]	0.475	3.82	0.468	ND	0.468	ND	0.209	7.90
Trip Blank	ND	ND	ND	ND	ND	0.346	ND	ND

DCB = Dichlorobenzene

DCE = Dichloroethylene

ND = Not Detected

[a] Carbon disulfide also was detected in the equipment blank at 0.917 μg/L.

[b] Samples also contained 1,2-dichloroethane at 0.370 and 0.404 (dup) μg/L.

Table 4-19. Results of Off-Site Analysis of Groundwater QC Samples for MNA Parameters

Sampling Location	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Methane (μg/L)	Ethane (μg/L)	Ethene (μg/L)
MW–4	50.8	5.28	104	0.0434	0.482	<0.25	<0.25
MW–4 dup	51.2	5.08	103	0.0342	0.565	<0.25	<0.25

SECTION 5
DISCUSSION OF RESULTS

Site characterization results are discussed below, followed by an evaluation of vapor intrusion for this site. Review of the analytical data sets indicates that the systems were within control and that the internal quality control checks performed by each laboratory generally were acceptable. The data are considered to be valid and defensible, with the possible exception of the on-site soil-gas data, as discussed later in this section.

5.1 Site Characterization

Groundwater, soil, and soil-gas samples were collected to characterize the current levels of contamination at the site. These results are discussed below.

The depth to bedrock was obtained for all 33 locations where probes were pushed plus the eight existing monitoring wells. The results are depicted in Figure 4-1. The depth to bedrock drops from roughly 35 ft (11m) bgs along Grand Avenue to >70 ft (21m) bgs behind the building. No depths greater than 70 ft (21m) could be obtained using the available direct-push equipment and this limited the ability to delineate the bedrock for most of Row "A."

5.1.1 Groundwater

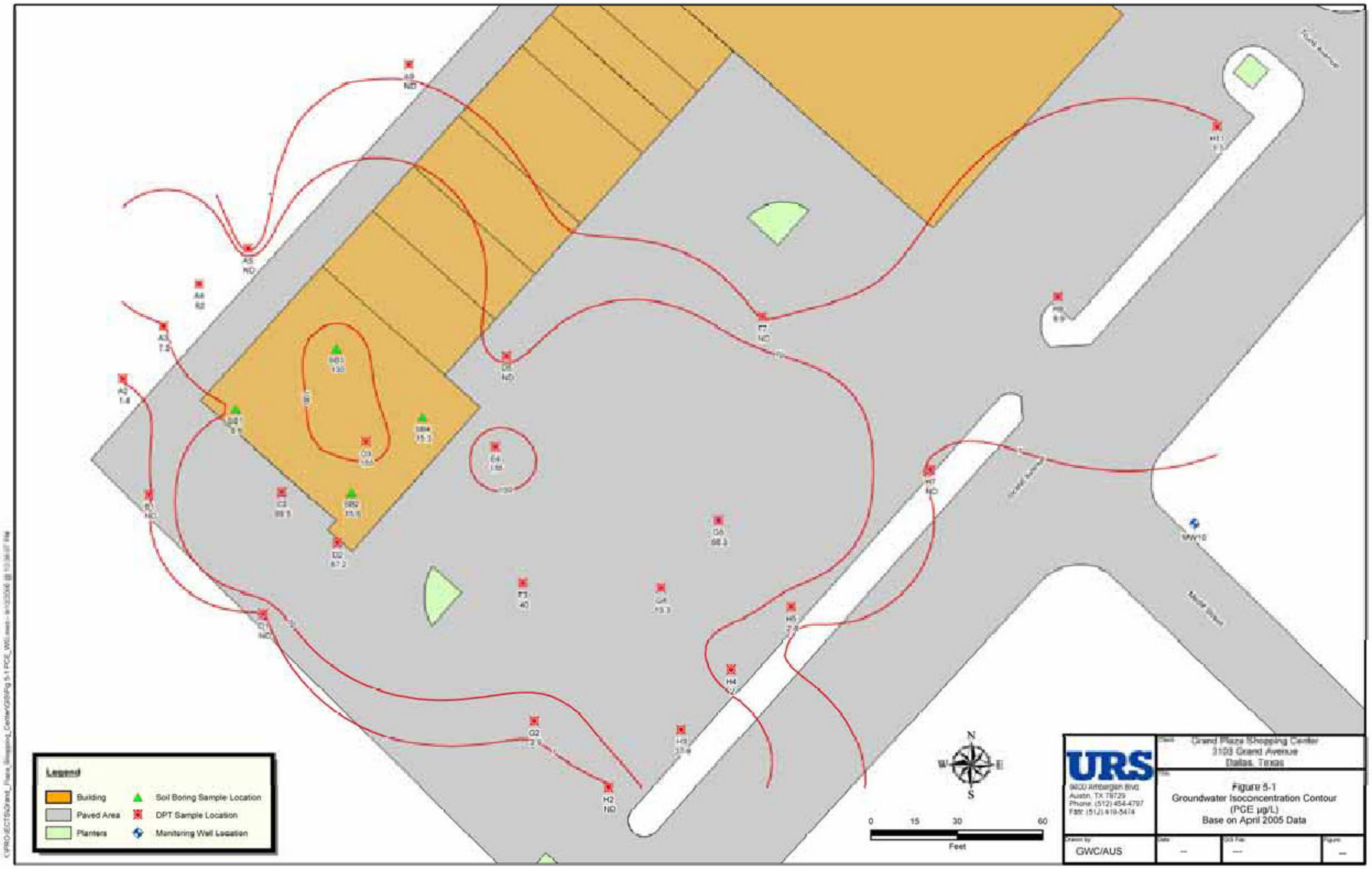
The on-site analytical results for groundwater data are plotted for PCE, TCE, and DCE in Figures 5-1, 5-2, and 5-3, respectively. The on-site analytical method could not distinguish between the cis- and trans- forms of DCE. The plots show that the highest concentrations of the target VOCs lie directly beneath the 60 ft by 70 ft (18 by 21m) southwest end of the strip mall, where the dry cleaner facility once operated. Some contamination has migrated towards Grand Avenue (e.g., locations G5 and H2). There also is some evidence of contamination behind the building (see data for location A4).

All VOC concentrations beneath the building are <0.4 ppm, while all concentrations outside the building are <0.1 ppm. All measured VOC concentrations are far below applicable state standards. The data indicate that the PCE has undergone substantial degradation to TCE and DCE, but no vinyl chloride was detected. In addition, benzene and toluene were not detected. Duplicate samples were analyzed on-site for seven locations. The results generally are within ±25% and are almost always within a factor of 2x.

The results for PCE and TCE for the last four rounds of groundwater monitoring (i.e., July 2003–December 2005) are shown in Table 5-1. The results indicate that the groundwater concentrations at the site generally are stable. Seven of the wells had very similar concentrations from sampling event to sampling event. The highest variability in sequential results occurred at MW-4, where TCE and PCE concentrations varied by as much as an order of magnitude. MW-6 and MW-7 also exhibited variability to some extent. PCE and TCE concentrations showed a gradual increase over three sampling events at MW–1.

The productivity of the shallow groundwater zone at Grand Plaza was evaluated at site monitoring wells using two methods: slug tests and a constant discharge test. Data from slug tests at two wells (MW-7 and MW-9) were used to estimate hydraulic conductivity values, which were subsequently converted into well yield values expressed in gallons per day (gpd). The constant discharge test (conducted at MW-10) allowed a direct measurement of minimum well yield, which was compared to the slug test results.

The tests were performed in accordance with state regulatory guidance (TCEQ, 2003), and duplicating select methodologies described by Butler, et. al.



Grand Plaza Shopping Center
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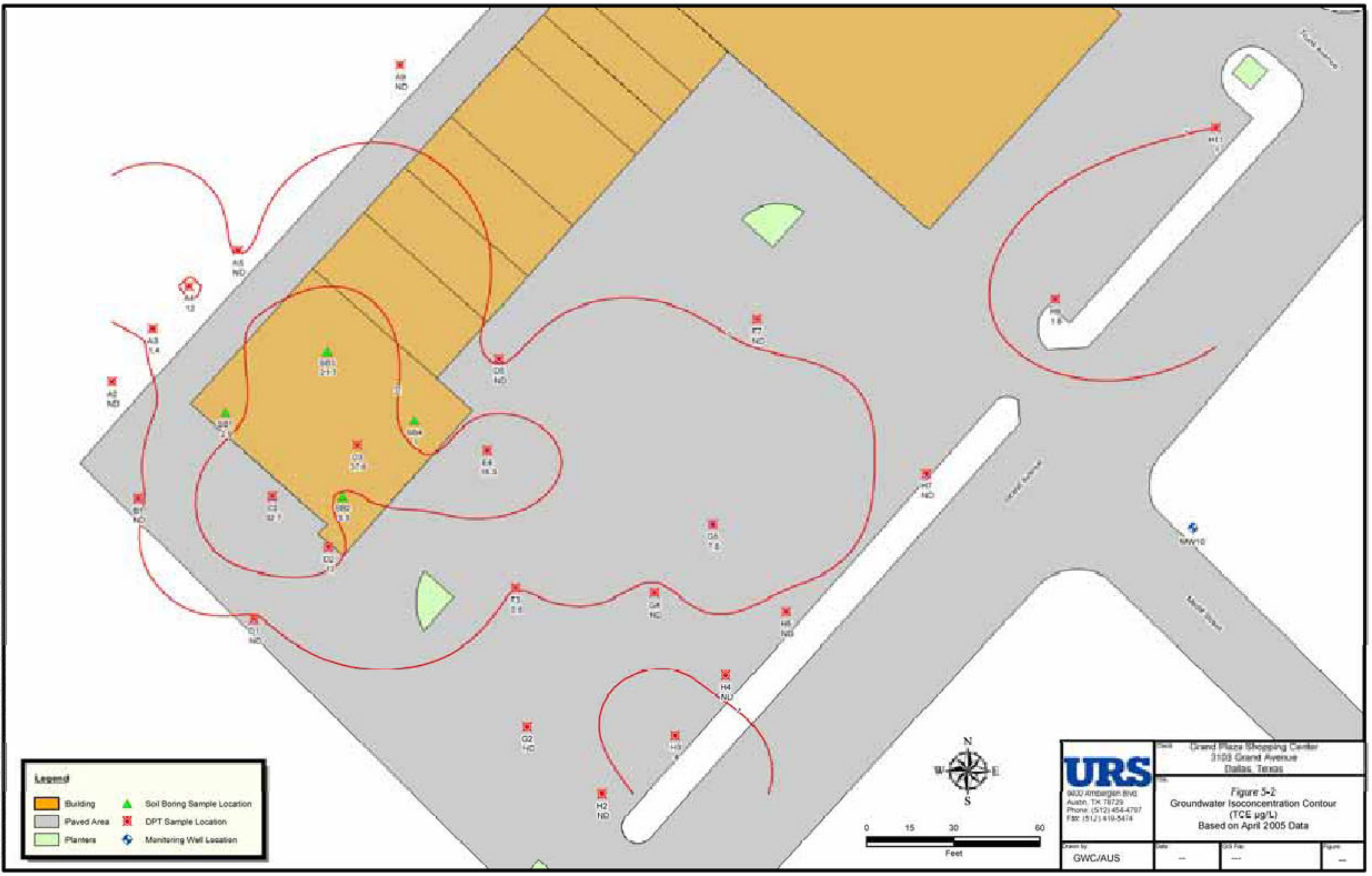
Dallas, Texas

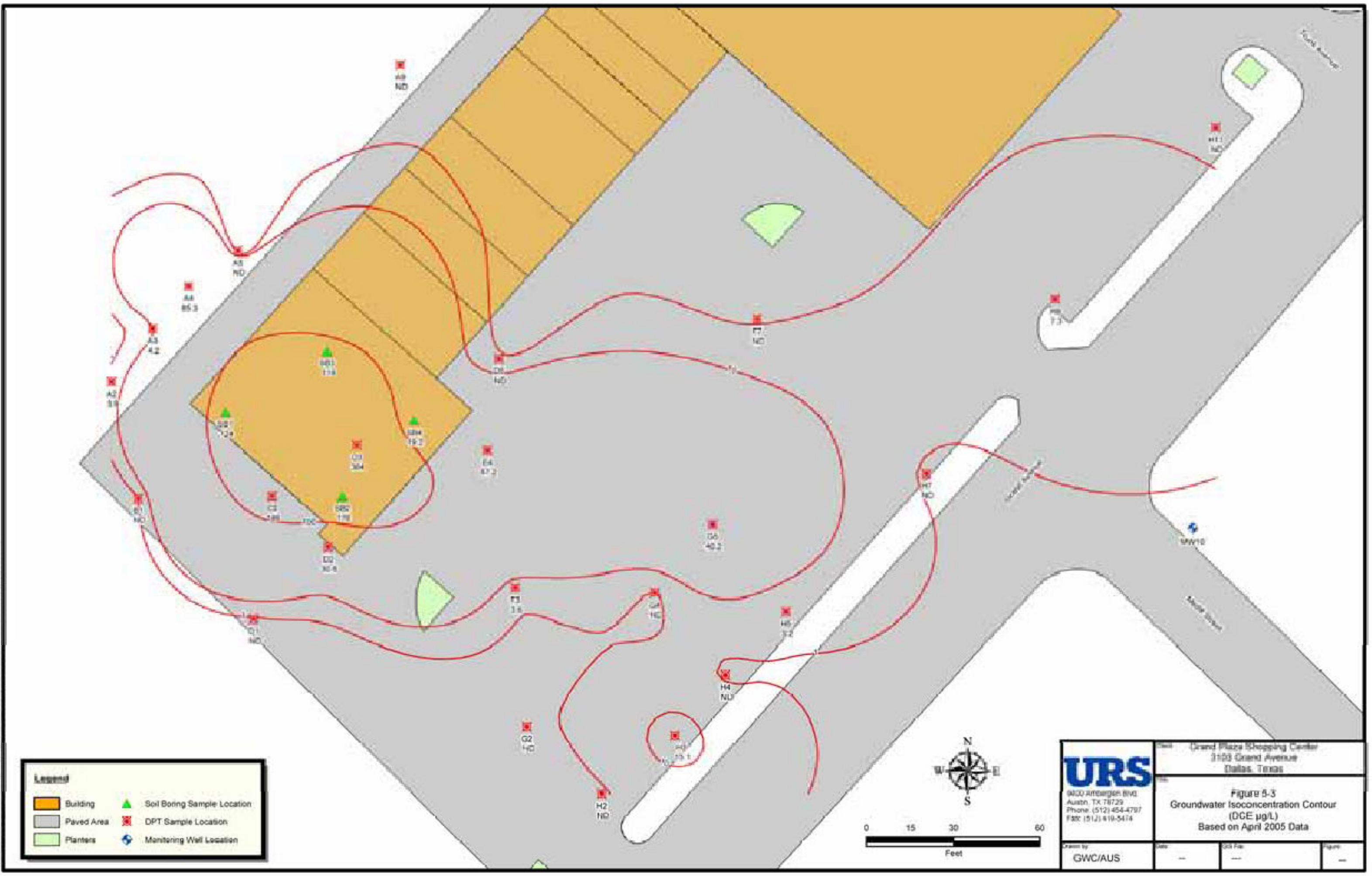
Figure 5-1
Groundwater Isoconcentration Contour
(PCE µg/L)
Base on April 2005 Data



Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas

Figure 5-2
Groundwater Isoconcentration Contour
(TCE µg/L)
Based on April 2005 Data

Drawn by:	Date:	GIS File:	Figure:
GWC/AUS	--	---	--



Legend

🟧	Building	▲	Soil Boring Sample Location
▨	Paved Area	☒	DPT Sample Location
🟩	Planters	●	Monitoring Well Location

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Dallas, Texas

Figure 5-3
Groundwater Isoconcentration Contour
(DCE µg/L)
Based on April 2005 Data

Drawn by:	Date:	GIS File:	Figure:
GWC/AUS	--	---	--

Table 5-1. PCE and TCE in Groundwater Over Time

Sampling Location	Tetrachloroethylene (μg/L)				Trichloroethylene (μg/L)			
	Dec 2005	Oct 2005	May 2004	July 2003	Dec 2005	Oct 2005	May 2004	July 2003
MW–1	--	184	160	144	--	22.2	18	14.8
MW–2	408	--	710	767	60.3	--	72	76.9
MW–3	--	4.64	4.4	4.22	--	2.16	2.1	2.37
MW–4	--	105	430	35.5	--	11.5	35	3.96
MW–5	--	25.4	28	26.3	--	3.61	3.2	3.32
MW–6	--	83.3	15	--	--	25.0	5.1	--
MW–7	--	9.57	6.0	--	--	1.77	1.6	--
MW–8	--	12.8	6.30	--	--	1.80	1.5	--
MW–9	0.513	1.15	--	--	3.99	4.42	--	--
MW–10	21.9	16.0	--	--	5.18	4.49	--	--

“—“ = No sample collected

(1996). Slug tests were performed as many as six times at each well in order to evaluate the reproducibility of the data. It was noted, particularly at MW-7, that “skin effects” within the well sand filter pack may have evolved during repeated testing, diminishing well recharge over time. The first two tests conducted at MW-7 yielded calculated hydraulic conductivities of approximately 140 and 200 ft/day (43 and 61 m/day), corresponding to calculated well yields of approximately 11,000 and 15,000 gal/day (42,000 and 57,000 L/day). The fifth and final test yielded a significantly lower calculated hydraulic conductivity of approximately 6.8 ft/day (2.1 m/day), corresponding to a calculated well yield of approximately 660 gpd (2,500 L/day). These presumed skin effects apparently were not as significant at MW-9. The first two tests conducted at MW-9 yielded calculated hydraulic conductivities of approximately 2.6 and 3.3 ft/day (0.80 and 1.0 m/day) corresponding to calculated well yields of approximately 16,000 and 20,000 gpd (61,000 and 76,000 L/day). The sixth and final test yielded a slightly lower calculated hydraulic conductivity of approximately 2.0 ft/day (0.6 m/day), corresponding to a calculated well yield of approximately 13,000 gpd (49,000 L/day). Note that calculated well yields are similar for both wells even though calculated hydraulic conductivity at MW-7 is two orders of magnitude greater than at MW-9. This occurs in calculation as a result of the saturated thickness of the aquifer at each location. The saturated thickness at MW-7 is approximately 5 ft (1.5m), versus 44 ft (13m) at MW-9.

A constant discharge test was conducted at MW-10, allowing a direct measurement of minimum well yield. During the test, an electronic water level indicator was used to measure the water level in MW-10 while a 12V submersible pump was operated at its maximum pumping rate, which was approximately 1 gallon per minute (3.8 L/min). Upon activation of the pump, 0.3 ft (9 cm) of drawdown occurred almost instantaneously. Thereafter, the water level remained constant as the pump discharged continuously for approximately 18 minutes, until the test was terminated. Extrapolated, the rate of discharge corresponds to a minimum well yield of approximately 1,400 gpd (5,300 L/day).

The results of both types of tests demonstrate that site well yields are significantly greater than 150 gpd (570 L/day), which is the threshold for Class 2 / Class 3 groundwater designation according to TCEQ Guidance Document RG-366/TRRP-8 (TCEQ, 2003). Therefore, the shallow groundwater zone at Grand Plaza is designated Class 2.

5.1.2 Soil

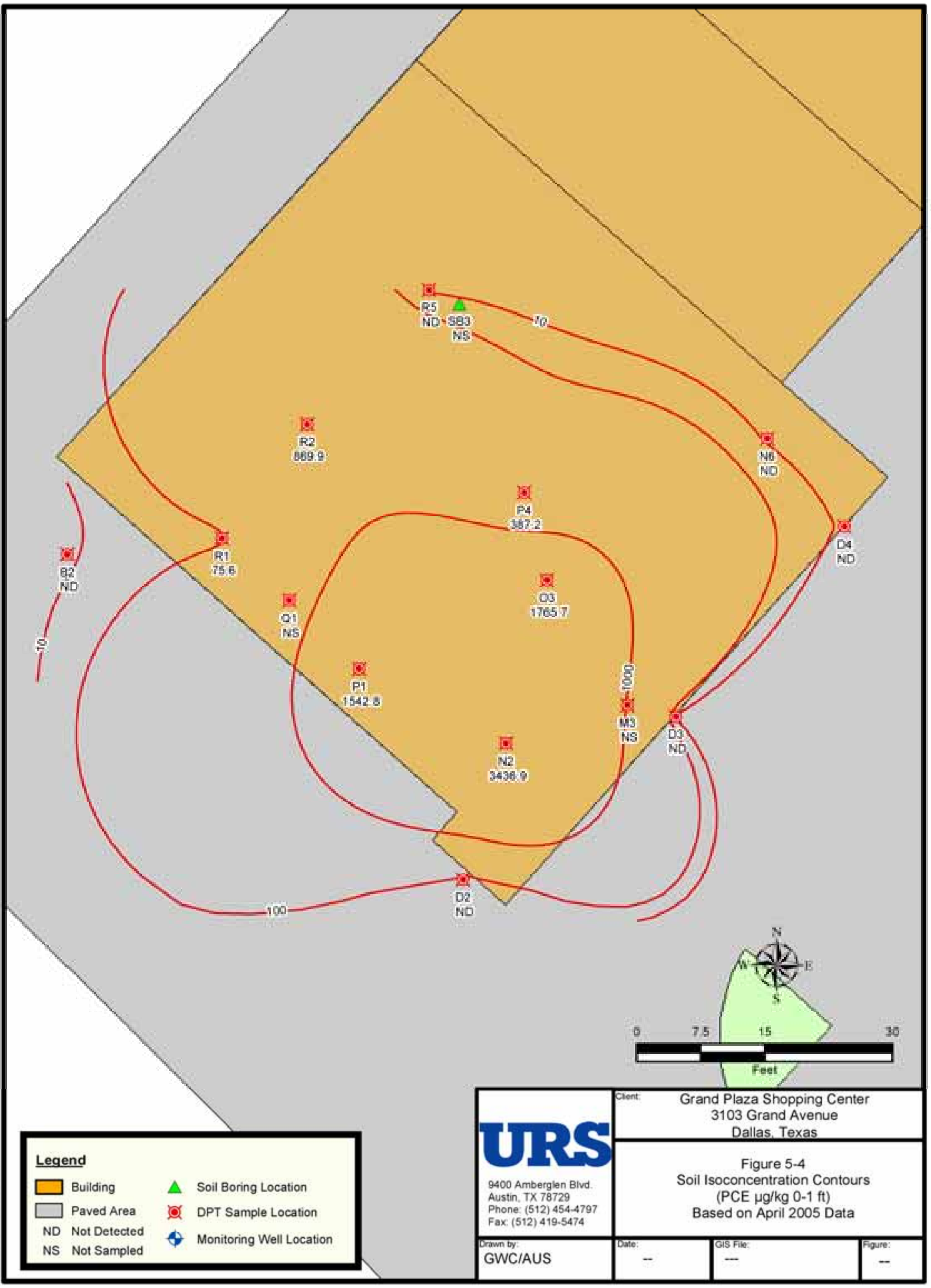
The on-site analytical results for soils are plotted for PCE in Figures 5-4, 5-5, and 5-6 for depths of 0–1 ft, 1–10 ft, and >10 ft (0–0.3, 0.3–3, and >3m), respectively. Similar plots are shown in Figures 5-7 through 5-9 for TCE and in Figures 5-10 through 5-12 for DCE. As previously noted, the on-site analytical method could not distinguish between the cis- and trans- forms of DCE. The plots indicate that the areas of higher contamination are relatively limited in size. Three-dimensional representations of the data are shown in Figures 5-13, 5-14, and 5-15 for PCE, TCE, and DCE, respectively.

All samples from outside the building were <0.4 ppm for all VOCs. Contamination was detected in all borings down to a depth of 20 ft (6m) bgs. Soil samples collected from beneath the building contained up to 3.4 ppm of PCE, 2.3 ppm of TCE, and 6.4 ppm of DCE. All measured VOC concentrations are far below applicable state standards. As with the groundwater samples, the data suggest that degradation of the PCE has occurred. Vinyl chloride, benzene, and toluene were not detected in any of the soil samples.

The highest concentrations of target VOCs generally occur near the surface and the concentrations tend to decrease below 12 ft (3.7m) bgs. However, concentrations >0.1 ppm were detected down to 20 ft (6m) at some locations (e.g., N2, P1, P4, and Q1). Contamination levels above 1 ppm for individual compounds are present to depths of at least 12 ft (3.7m) and contamination levels above 0.5 ppm are present to depths of at least 28 ft (8.5m)(see data for N2).

Duplicate samples were analyzed for two depths at one location. Only PCE was detected in these samples and the results for the duplicates agree to within a factor of 2x.

Aliquots of water extracts from three soil samples were analyzed by an off-site laboratory for confirmatory purposes. For the four data pairs where the compounds were detected in both the on-site and off-site analyses, the average relative percent difference (RPD) was 44% (based on the absolute values of the individual RPDs).



Client: Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas

Figure 5-4
Soil Isoconcentration Contours
(PCE µg/kg 0-1 ft)
Based on April 2005 Data

Drawn by: GWC/AUS
Date: --
GIS File: ---
Figure: --

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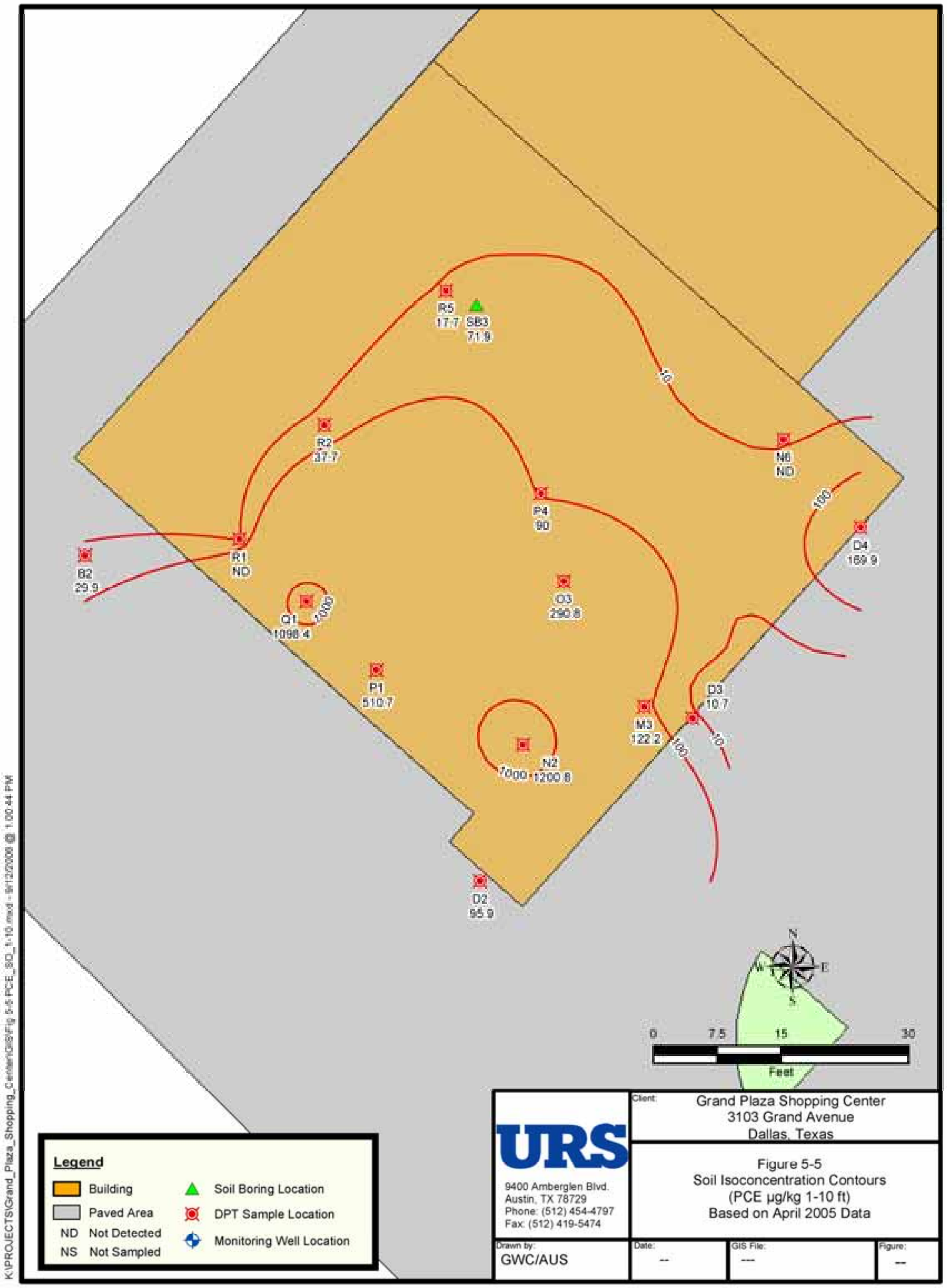
R5
17.7
SB3
71.9
10
R2
37.7
N6
ND
P4
90
100
D4
169.9
R1
ND
B2
29.9
Q1
1098.4
1000
O3
290.8
P1
510.7
D3
10.7
M3
122.2
10
100
1000
N2
1200.8
D2
95.9
N
W
E
S
0
7.5
15
30
Feet
Legend
Building
Paved Area
ND Not Detected
NS Not Sampled
Soil Boring Location
DPT Sample Location
Monitoring Well Location
URS
9400 Amberglen Blvd.
Austin, TX 78729
Phone: (512) 454-4797
Fax: (512) 419-5474
Client:
Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas
Figure 5-5
Soil Isoconcentration Contours
(PCE µg/kg 1-10 ft)
Based on April 2005 Data
Drawn by:
GWC/AUS
Date:
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GIS File:

Figure:
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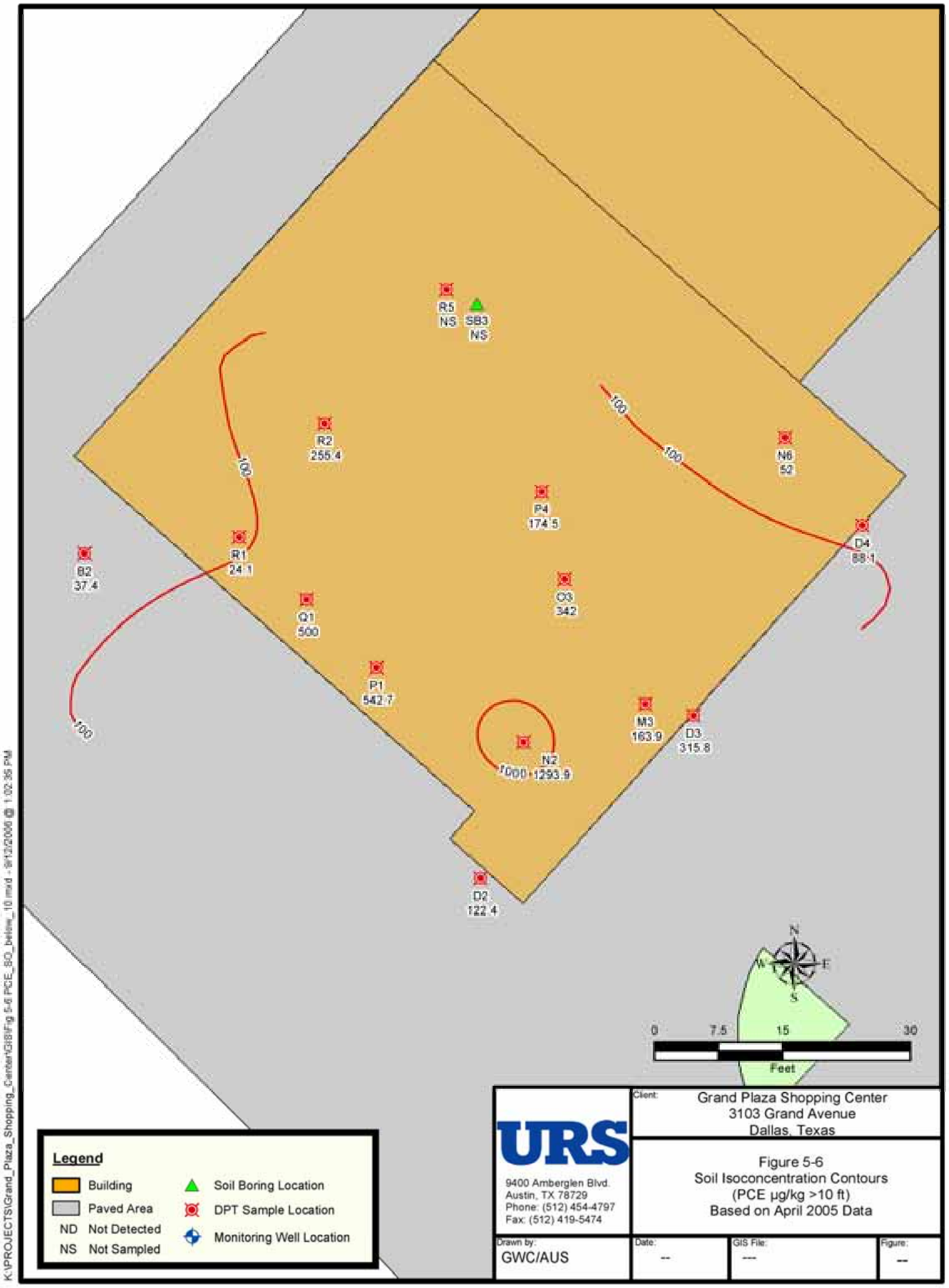

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Fax: (512) 419-5474

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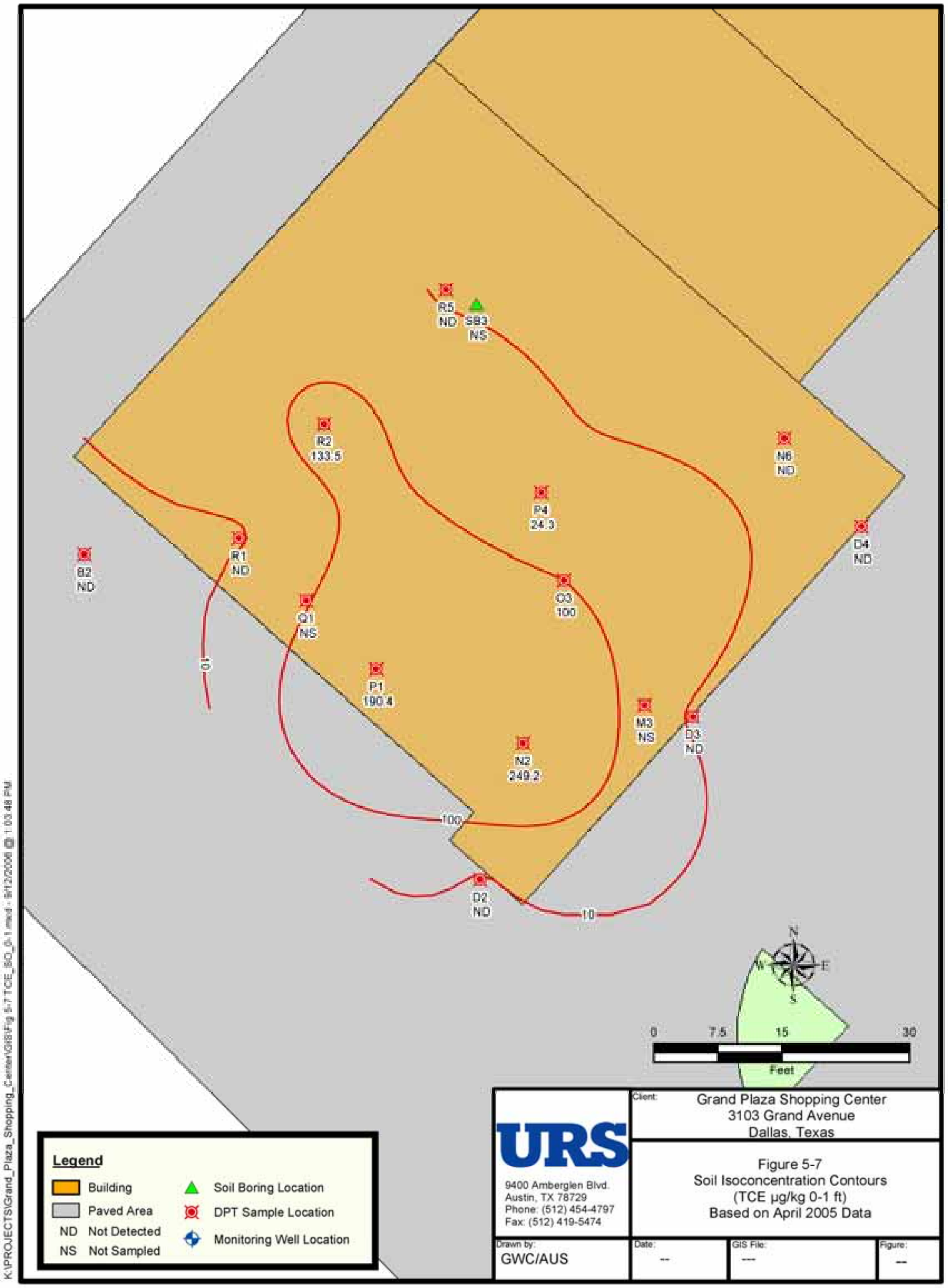
Figure 5-6
Soil Isoconcentration Contours
(PCE µg/kg >10 ft)
Based on April 2005 Data

Drawn by:	Date:	GIS File:	Figure:
GWC/AUS	--	---	--


R5
ND
SB3
NS
R2
133.5
N6
ND
P4
24.3
D4
ND
R1
ND
B2
ND
O3
100
Q1
NS
10
P1
190.4
M3
NS
D3
ND
N2
249.2
100
D2
ND
10
N
W
E
S
0
7.5
15
30
Feet
Legend
Building
Paved Area
ND Not Detected
NS Not Sampled
Soil Boring Location
DPT Sample Location
Monitoring Well Location
URS
9400 Amberglen Blvd.
Austin, TX 78729
Phone: (512) 454-4797
Fax: (512) 419-5474
Client:
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3103 Grand Avenue
Dallas, Texas
Figure 5-7
Soil Isoconcentration Contours
(TCE µg/kg 0-1 ft)
Based on April 2005 Data
Drawn by:
GWC/AUS
Date:
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GIS File:

Figure:
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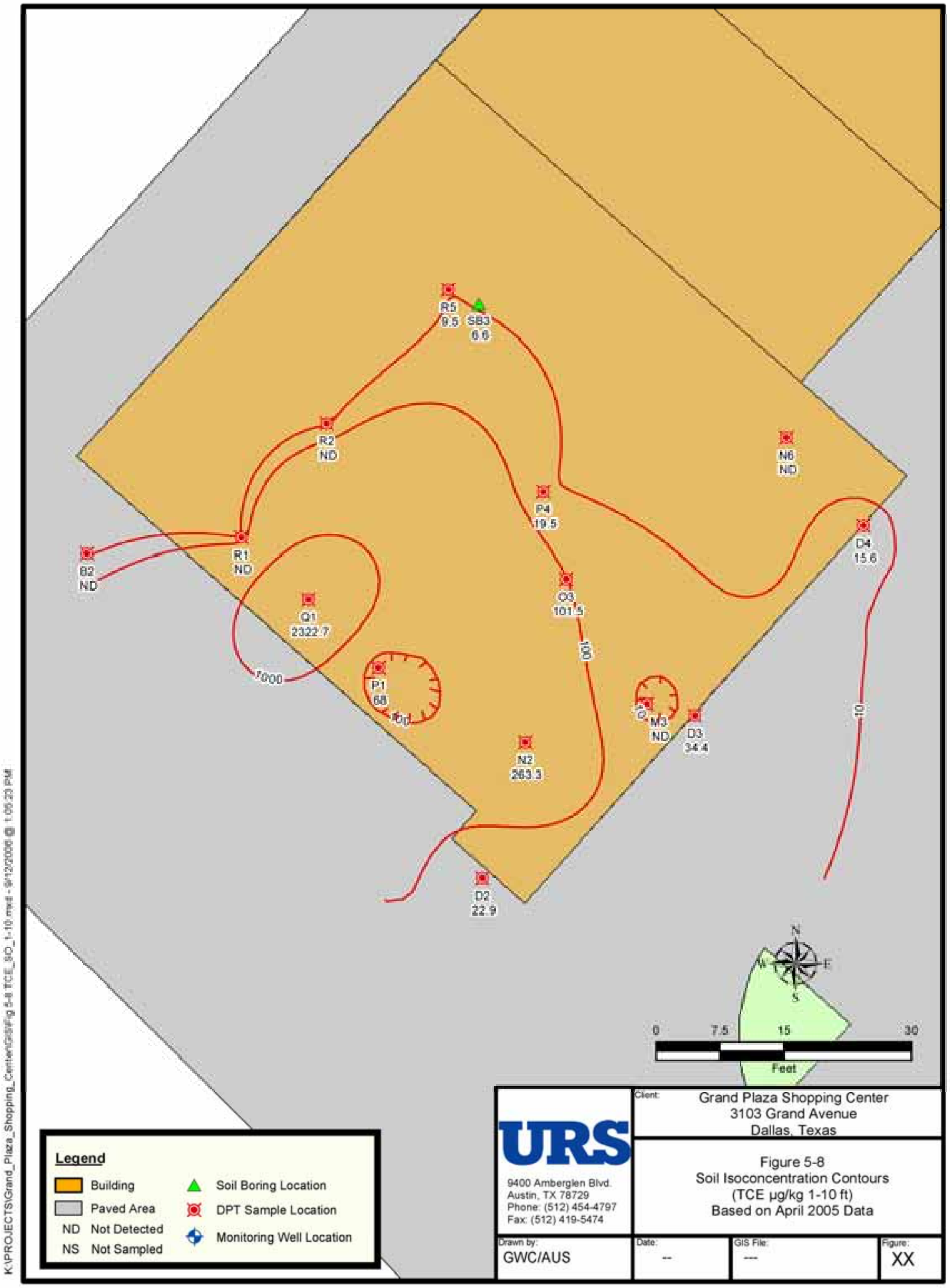
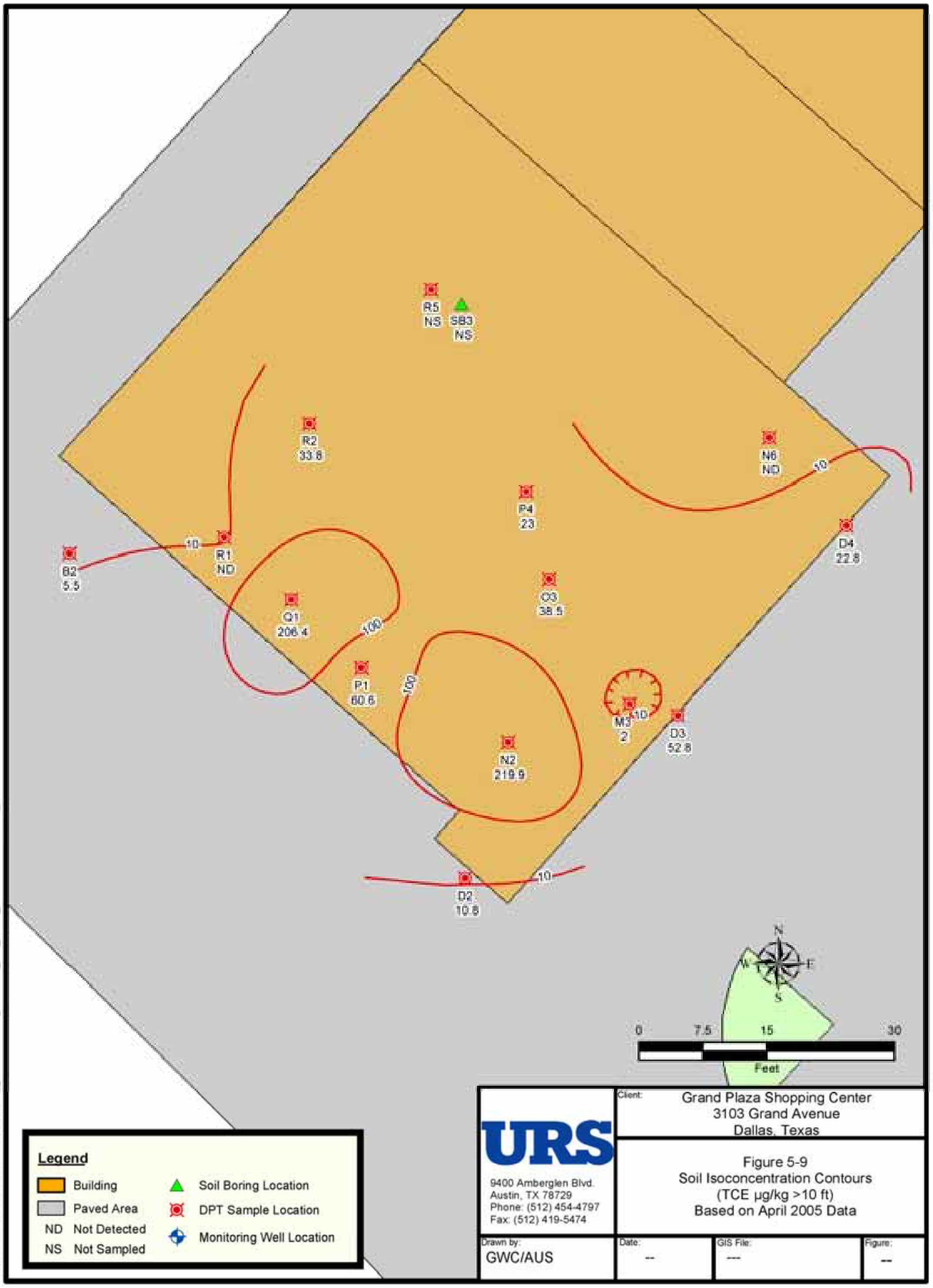


Figure 5-8
Soil Isoconcentration Contours
(TCE µg/kg 1-10 ft)
Based on April 2005 Data



Grand Plaza Shopping Center
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Dallas, Texas

Figure 5-9
Soil Isoconcentration Contours
(TCE µg/kg >10 ft)
Based on April 2005 Data

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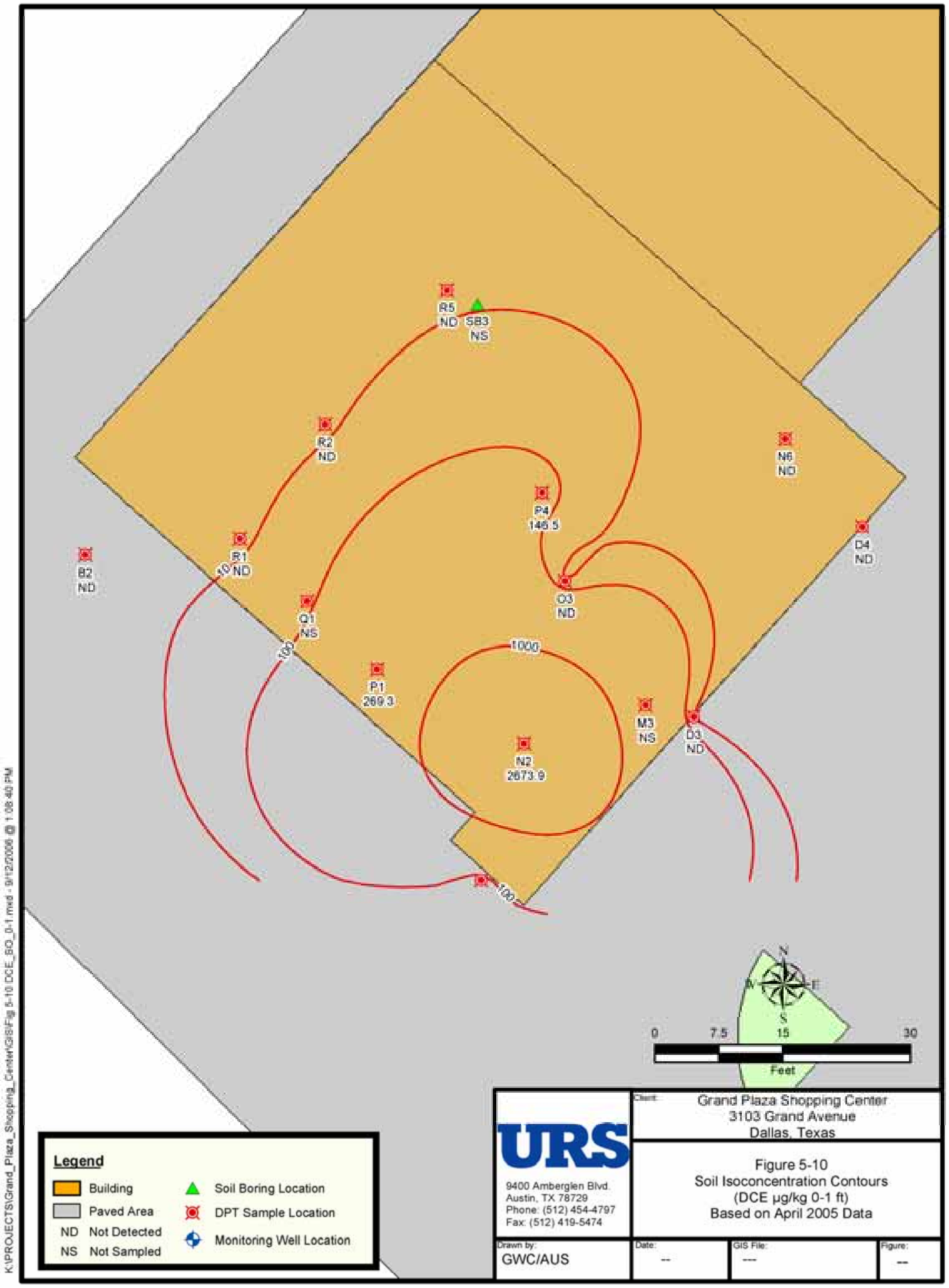
R5
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SB3
NS
R2
ND
N6
ND
P4
146.5
D4
ND
R1
ND
10
B2
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ND
Q1
NS
100
1000
P1
269.3
M3
NS
D3
ND
N2
2673.9
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N
W
E
S
0
7.5
15
30
Feet
Legend
Building
Paved Area
ND Not Detected
NS Not Sampled
Soil Boring Location
DPT Sample Location
Monitoring Well Location
URS
9400 Amberglen Blvd.
Austin, TX 78729
Phone: (512) 454-4797
Fax: (512) 419-5474
Client:
Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas
Figure 5-10
Soil Isoconcentration Contours
(DCE µg/kg 0-1 ft)
Based on April 2005 Data
Drawn by:
GWC/AUS
Date:
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GIS File:

Figure:
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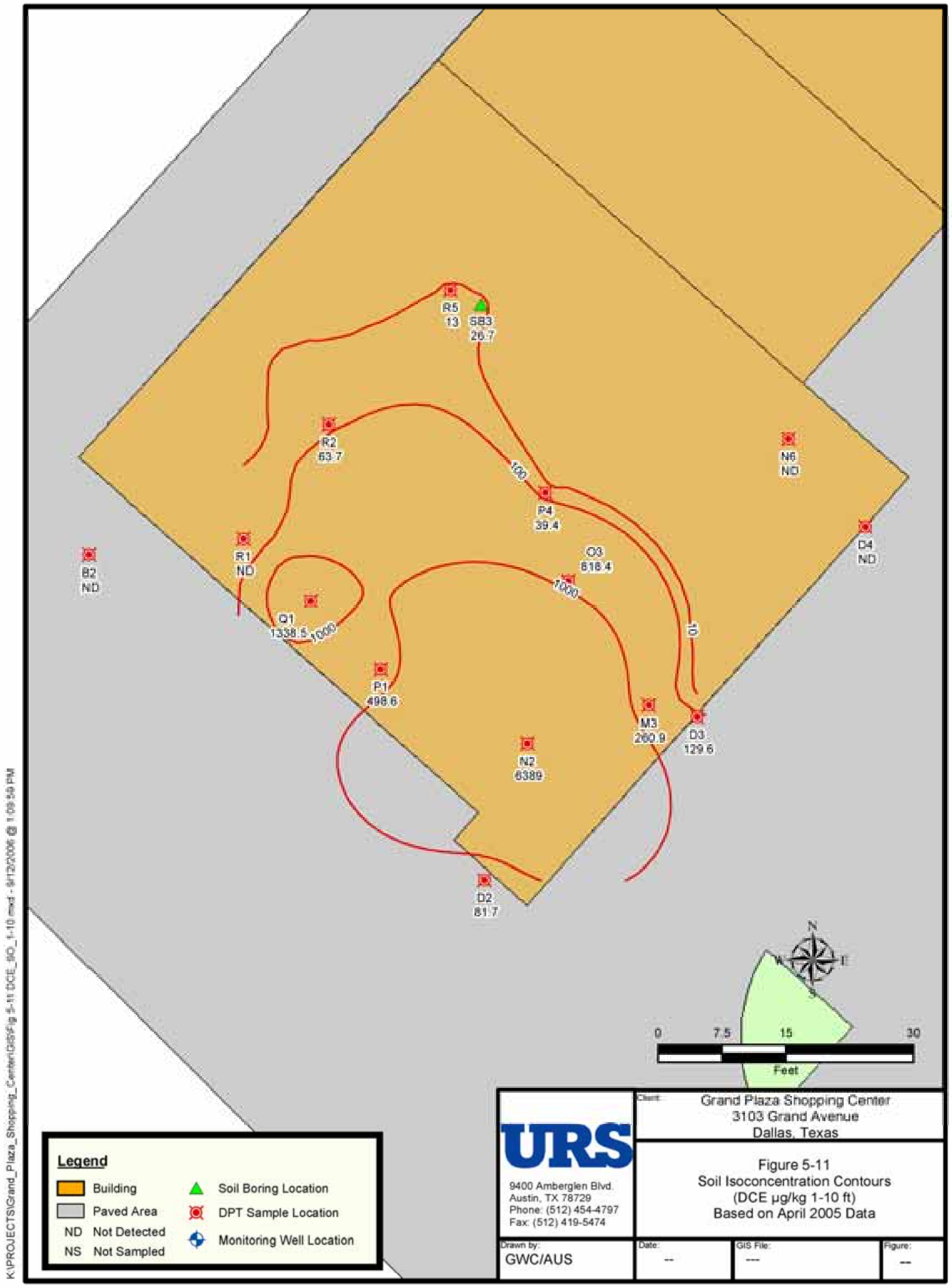
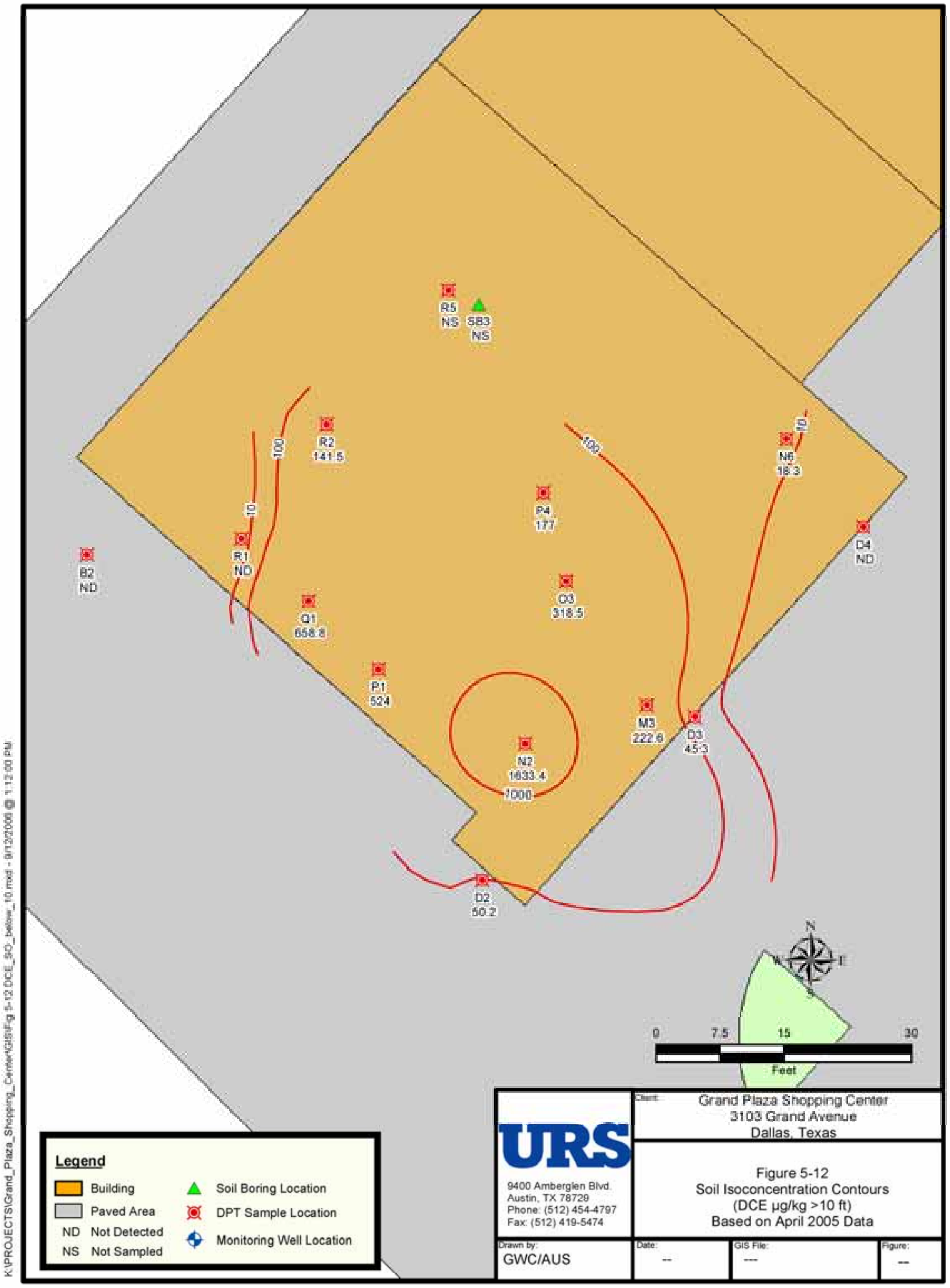


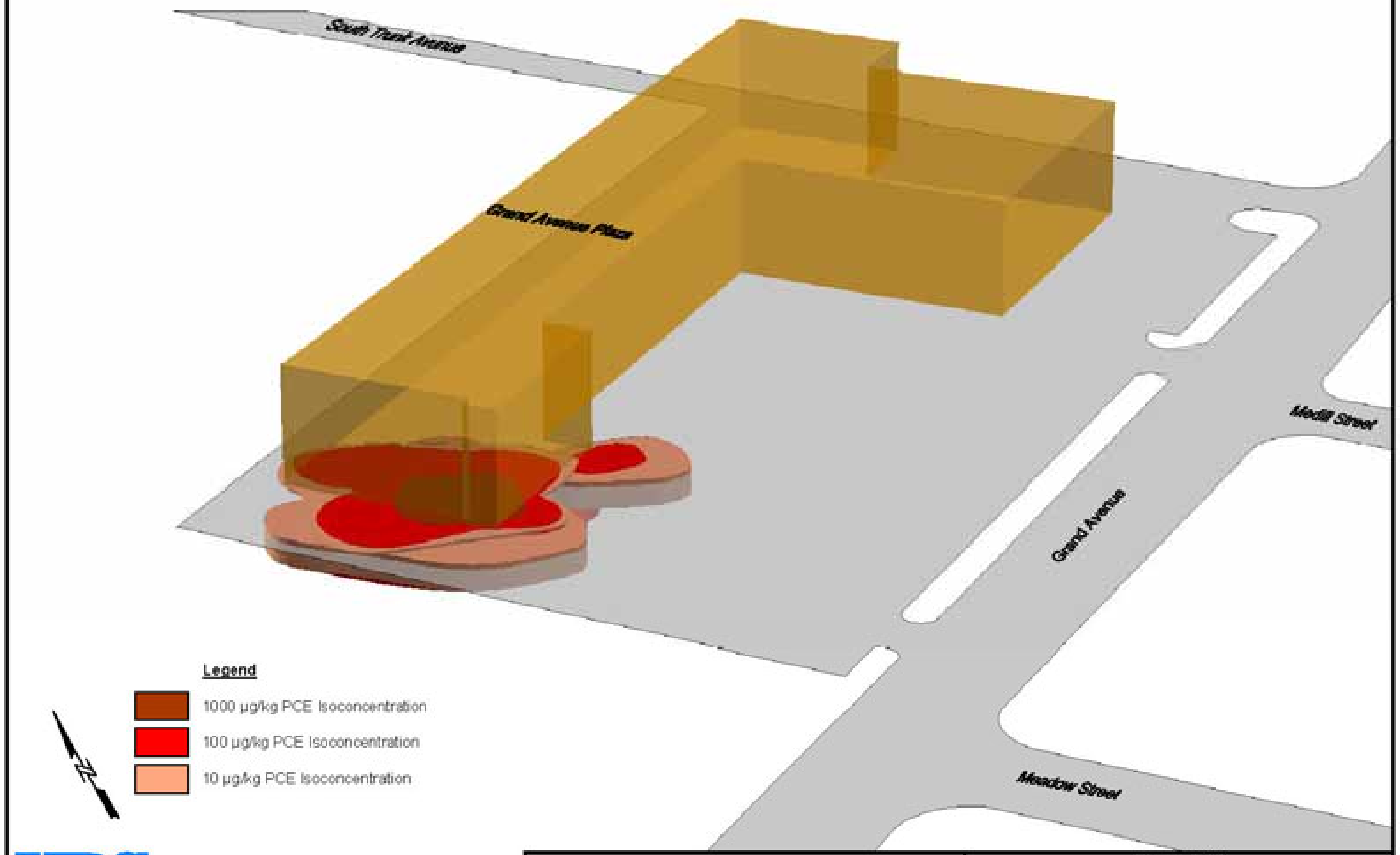
Figure 5-11
Soil Isoconcentration Contours
(DCE µg/kg 1-10 ft)
Based on April 2005 Data



Grand Plaza Shopping Center
3103 Grand Avenue
Dallas, Texas

Figure 5-12
Soil Isoconcentration Contours
(DCE µg/kg >10 ft)
Based on April 2005 Data

File: X:\PROJECTS\Grand_Plaza_Shopping_Center\3D_Scenes\3d_plumes.dwg Layout: Fig 5-13 PCE Plotted: Sep 27, 2006 — 10:59am



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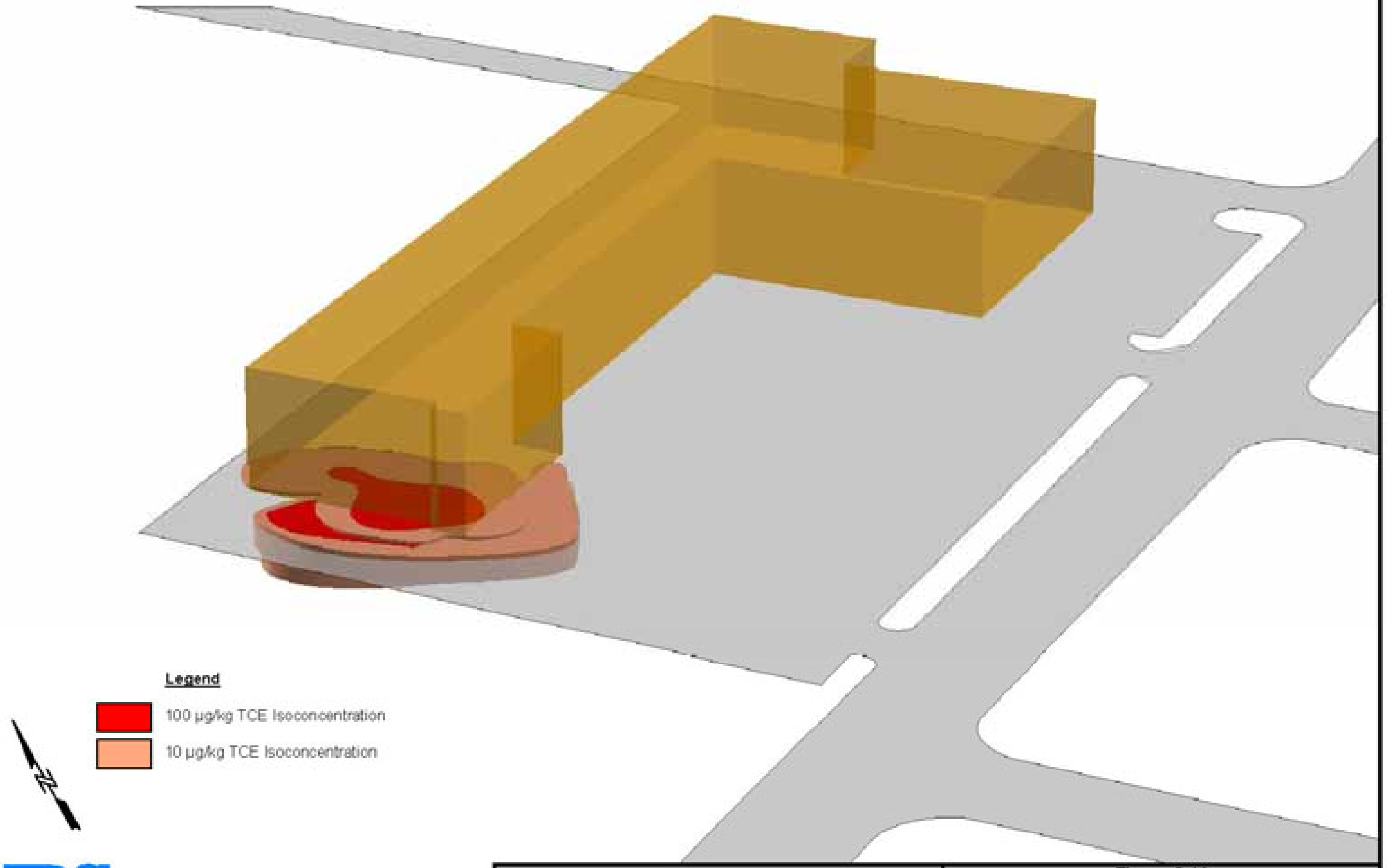
Grand Avenue Plaza 3103 Grand Avenue Dallas, Texas		**Figure 5-13** **3-D PCE Plume** **Based on April 2005** **Soil Data**
DATE: Sep 27, 2006	DRWN:	3d_plumes.dwg

File: K:\PROJECTS\Grand_Plaza_Shopping_Center\3D_Scene\3d_plumes.dwg Layout: Fig 5-14 TCE Plotted: Sep 27, 2006 - 10:53am



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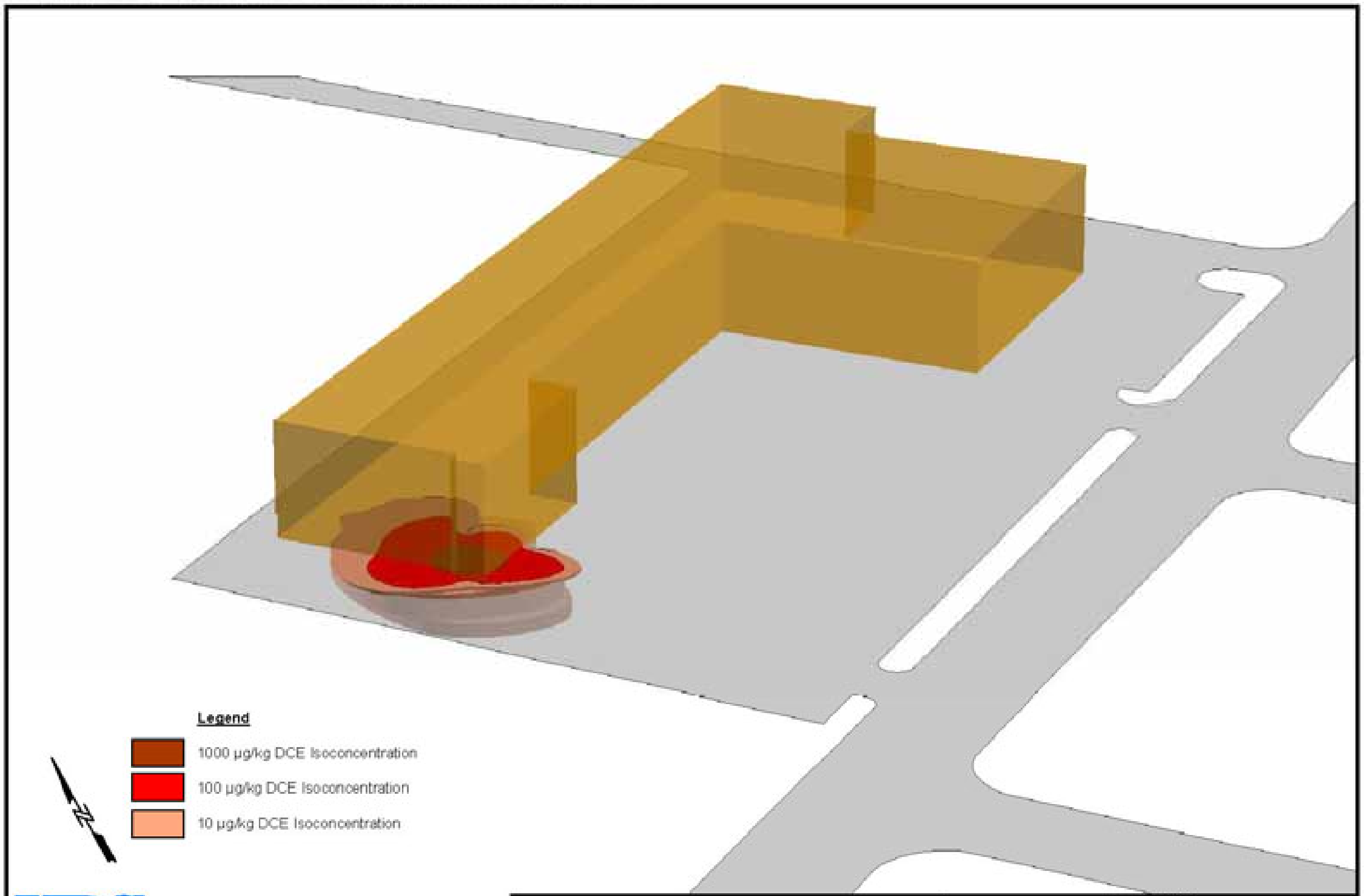
3103 Grand Avenue
Dallas, Texas

DATE: Sep 27, 2006 DRWN: 3d_plumes.dwg

Figure 5-14
3-D TCE Plume
Based on April 2005
Soil Data



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Dallas, Texas

Figure 5-15
3-D DCE Plume
Based on April 2005
Soil Data

DATE: Sep 27, 2006	DRWN:	3d_plumes.dwg

5.1.3 On-Site Soil-Gas

Soil-gas samples were obtained at a depth of 5 ft (1.5m) bgs from 10 locations and analyzed on-site. In addition to the shallow soil-gas samples, soil-gas samples were collected at the four sub-slab soil-gas sampling locations. Only PCE was detected in the soil-gas samples at 5 ft (1.5m) depth; all other compounds were non-detect (ND). No PCE was detected in the soil-gas samples collected outside the building or in two of the six soil-gas samples at 5 ft (1.5m) bgs under the building. The highest concentration was 1,110 $\mu g/m^3$ (7.5 ppmv) at location R2.

The on-site analysis of the sub-slab soil-gas samples showed relatively high concentrations of PCE at all four locations where samples were obtained. All other compounds were ND. The measured concentrations for PCE were:

- SS1 = 25,300 $\mu g/m^3$ (172 ppmv);
- SS1B = 28,200 $\mu g/m^3$ (191 ppmv);
- SS3 = 920 $\mu g/m^3$ (6.2 ppmv); and
- SS4 = 239 $\mu g/m^3$ (1.6 ppmv).

The sub-slab sampling locations are shown in Figure 3-4. On the sampling array, Location SS1 was near N3, in the area where the dry cleaning machines once were located. Location SS1B was two ft from SS1 and was used after SS1 became resistant to flow. Location SS2 was between N4 and N5 on the sampling array shown in Figure 3-1. Location SS3 was between P2 and Q2, and Location SS4 was near S2.

Samples SS1 and SS1B were collected sufficiently close together to be considered duplicate samples. The RPD for this sample pair is 11%. Four sequential samples were collected at location SS3 (a regular sample and three replicates). The replicate samples showed somewhat lower concentrations than the regular sample: –8%, –35%, and –23%.

Given the high concentrations that were detected, the on-site analysis could have relied upon a direct injection approach rather than the use of sorbent tubes. The on-site soil-gas data exhibit a consistent low bias compared with the off-site analytical results. One possibility is that the sorbent material may have become saturated with VOCs. Overall, the on-site soil-gas data are believed to be less accurate than the on-site groundwater and soil data.

5.2 Evaluation of Vapor Intrusion

The off-site analytical results for soil-gas, indoor air samples, and tracer gas tests are discussed below, followed by a discussion of the potential for vapor intrusion at this site.

5.2.1 Off-Site Analysis of Soil Gas

Shallow soil-gas samples were collected at at a depth of 5 ft (1.5m) bgs from six locations and three sub-slab soil-gas samples were collected. The PCE in the shallow soil gas ranged from 0.039 to 0.71 ppmv. The TCE concentrations were similar to the PCE concentrations, whereas the DCE tended to be higher (up to 29 ppmv). The presence of TCE, DCE, and VC is additional evidence that the PCE has degraded in the past.

In addition to the compounds shown in Table 4-9, one or more of the samples contained hexane, trans-1,2-DCE, m/p-xylene, or 2,2,4-trimethylpentane. The amount of trans-1,2-DCE was generally <10% of the amount of cis-1,2-DCE. The concentration of 2,2,4-trimethylpentane (iso-octane) ranged from 0.14 to 1.7 ppmv in the shallow soil-gas samples. Gasoline releases are the most likely source of this compound. Some samples also showed traces of compounds thought to be laboratory artifacts (i.e., ethanol, acetone, or methyl-ethyl ketone [MEK]).

The sub-slab soil-gas data exhibited considerable spatial variability. For example, two of the three sub-slab soil-gas samples had PCE concentrations between 3 and 9 ppmv, whereas the third sample had 2,600 ppmv of PCE (0.26%)(18,000,000 $\mu g/m^3$). This sample was collected from the middle of the restaurant and also had significant concentrations of TCE and cis-1,2-DCE. The off-site data for PCE are consistently higher than the on-site analytical results for the same location. The off-site data should be considered more representative of site conditions.

The sub-slab samples were each collected adjacent to a shallow soil-gas sample. The comparison of the shallow and sub-slab soil-gas data is shown in Table 4-10. The comparison generally shows that the PCE concentrations are highest immediately beneath the slab. The maximum measured values for shallow soil-gas and sub-slab soil-gas did not coincide spatially.

No physical barriers to vapor transport were found in the examination of the building slab based on the sound checks. Pressure differential measurements made under induced vacuum indicated that the fill directly underneath the slab is amenable to vapor flow. While drilling holes in the slab it was found that the slab is only about 4 in. (10 cm) thick in places. Tile floor covering precluded a thorough examination of the slab for cracks.

Soil gas data at the site indicate that chemical concentrations vary spatially, decreasing significantly with distance from a small "hot spot". The data suggest that the contamination has largely remained in place under the slab near its release point with only limited vertical and lateral transport. The lack of gas-phase lateral migration within the fill material directly beneath the slab is somewhat surprising, given the decades of time that the contamination has been in place and the expected rates of diffusion in the air-filled pore spaces beneath the slab.

5.2.2 Off-Site Analysis of Indoor and Ambient Air Samples

Two indoor air samples and one outdoor ambient air sample were collected during the first round of sampling. PCE was detected in the indoor air samples at concentrations of 10 to 13 ppbv. TCE was detected at 0.52 to 0.65 ppbv and cis-1,2-DCE was detected at 1.1 to 1.6 ppbv. The ambient air sample had low levels of PCE (0.11 ppbv), but the ambient air does not appear to be a significant source of the compounds detected in the indoor air samples.

The measured indoor air concentrations may have been biased high due to two factors. One, the drilling through the floor in the days preceding air sampling likely created a pathway for subsurface vapors to enter the building. The exposed soil cores in the room also may have been an emissions source. Two, the HVAC system was not operating for at least 12 hours prior to the start of the indoor air sampling, so dilution of any emissions would have been minimal.

Based on the results of the initial site characterization, additional samples were collected to evaluate the potential for vapor intrusion. As shown in Tables 4-11 and 4-12, indoor air samples were collected at two locations during the first round of sampling and at one location during the second round of sampling. The results for the two rounds of sampling showed similar levels of VOCs in the indoor air.

Overall, PCE was detected in the indoor air at about 12 ppbv (83 μg/m^3). The agreement among the indoor air samples is good, despite the difference in conditions between the two sampling events. As previously discussed, during the first round of sampling, the space was unoccupied and the HVAC system was not in use during the sampling event nor during the preceding days. During the second round of sampling, the HVAC system was in regular use.

As shown in Table 4-12, a grab sample was collected about 24 hours prior to the second round of sampling at a time when the building HVAC system had been operating at a high rate overnight. This sample had only about 25% of the PCE, TCE, and cis-DCE of the samples detected in the time-integrated samples collected the following day. This suggests that there can be significant short-term temporal variability in indoor VOC concentrations at this site.

5.2.3 Tracer Gas Tests

Neither helium nor SF_6 was detected in the indoor air prior to the tracer gas releases. The time-integrated sample collected 24 hours later had <0.020% helium. Using equation 3-1 and the helium release rate of 0.18 m^3 hr^{-1}, the ventilation rate within the restaurant portion of the building (Q_{Bldg}) is estimated to be >900 m^3 hr^{-1}. The restaurant area has a footprint of 184 m^2 and a volume of 481 m^3. Therefore, the building air exchange rate is estimated to be >1.9 air changes per hour (ACH).

Four grab samples also were collected after the tracer gas release was initiated and helium was detected in three of the four samples, with values ranging from <0.014% to 0.057%. The variability may be due to incomplete mixing in the indoor air space as evidenced by the variability between the helium and SF_6 concentrations. The variability also is thought to reflect changes in the actual ventilation rate as the HVAC system and fry-station exhaust hood turned on and off. The experimental design did not address measurements of the building ventilation as a function of exhaust hood use. Real-time measurements of helium concentration should be included in any future, similar studies. The average helium concentration was 0.031% if the detection limit is substituted for the non-detect values. This yields a ventilation rate of 573 m^3 hr^{-1} and 1.2 ACH.

The time-integrated measurement of SF_6 was 0.57 ppbv and two grab samples collected during the same time frame had similar results. The detection of SF_6 within the building confirms that vapor intrusion is occurring. Two additional measurements of SF_6 were made after use began of the fry-station exhaust hood. The hood increased the pressure differential between the building and soil and thereby is believed to have increased the rate of Q_{soil}. The threefold increase in concentration reflects an increase in Q_{soil} of >3, if the exhaust hood increased the building ventilation rate.

Pressure differential measurements were made to confirm the effect of the fry-station exhaust hood. Two holes were drilled through the slab 15 to 30 ft (5 to 10m) from the exhaust hood and the building pressure differential was measured with the exhaust hood off and again with the exhaust hood on. The measurement locations are shown in Figure 3-4. The use of the exhaust hood changed the building pressure differential from +0.002 to –0.003 in. H_2O at one location and from +0.001 to –0.006 in. H_2O at the second location. The positive sign indicates that air flow is from the interior space into the subsoil, whereas a negative sign indicates that air flow is from the subsurface. So, the effect of the exhaust fan was to switch the soil-gas flow from positive to negative. The magnitude of this effect was about 1.5 Pa. For comparison, the US EPA guidance assumes a continuous building pressure differential (ΔP) of 4 Pa (EPA, November 2002).

The measurements of pressure differential at the three sub-slab sampling locations during April 2005 were all non-detect (<0.005 in. H_2O). As previously noted, the HVAC system and exhaust hood were not in regular use at the time.

5.2.4 Evaluation of Vapor Intrusion

Vapor intrusion (VI) is the migration of gas-phase chemicals from the subsurface into buildings or other structures. It is only in the last few years that vapor intrusion of VOCs has become a general issue for sites with subsurface contamination due to petroleum fuels or chlorinated solvents. Federal guidance has been published (US EPA, November 2002), as well as guidance by various State Agencies (Eklund, et al., 2006).

Vapor intrusion studies typically address the potential risk from chronic exposure to very low concentrations of potential carcinogens. It is the incremental increase in indoor air concentration that is the issue, not the absolute concentration itself. Given the typical background levels of VOCs in houses and office buildings, it often is difficult or impossible to measure vapor intrusion directly using indoor air measurements. Therefore, alternative evaluation approaches are often employed. A standard modeling approach is available (Johnson and Ettinger, 1991)(US EPA, 2003b), but there are concerns that the model may be too conservative for some scenarios or that the model can be misused. Most current guidance emphasizes evaluating vapor intrusion using soil-gas measurements made near the buildings of interest.

The ratio of indoor air to soil-gas concentrations is often evaluated in vapor intrusion studies. This ratio typically is called the attenuation factor or α. Published values of α tend to be <0.001. In other words, the soil gas is diluted by a factor of >1,000 inside a building. The EPA default α value for screening purposes currently is 0.1, but is expected to decrease to 0.02 when the 2002 EPA guidance is revised sometime in 2007.

It is typical practice to use the maximum subsurface value rather than the mean or median value when calculating α for a given site. The three sub-slab soil-gas samples had 18,000,000; 26,000; and 59,000 $\mu g/m^3$ of PCE. The three indoor air samples had 85, 68, and 96 $\mu g/m^3$, for a mean of 83 $\mu g/m^3$. Therefore, $\alpha = 5.3 \times 10^{-6}$ using the maximum values and $\alpha = 1.4 \times 10^{-5}$ using the average values. The values of α for other compounds detected in the sub-slab soil-gas are also in the 10^{-6} range using the maximum values. These results are not unreasonable. In another study, one of the authors has measured attenuation coefficients of roughly 1×10^{-5} in multiple buildings with decades-old surface spills and localized high concentrations of chlorinated solvents in the sub-slab soil gas (Rehage, et al., 2006).

The sub-slab monitoring locations were biased towards areas of suspected contamination. So, the average value calculated from the three sub-slab measurements is thought to be biased high from the "true" value. Given the very high degree of subsurface spatial variability in the concentration of PCE and other VOCs, the average value is essentially equal the maximum value divided by the number of measurements (n). Increasing n would likely lead to a linear decrease in α calculated from average values, unless a 2nd "hot spot" were found.

The concentration of VOCs in the subsurface should be relatively stable, whereas the indoor air concentration was found to vary by about a factor of 4x over a one-day period. Given that α is a simple ratio of the two, it also would vary by this same factor of 4x. This short-term temporal variability is thought to be due to changes in the pressure differential between the building and the subsurface. When the exhaust fan in the restaurant is off, there is little or no pressure-driven airflow of vapors into the building. When the exhaust fan is on, there is a driving force for vapor intrusion.

The US EPA and others are compiling data, but there are relatively few published values for α in the open literature. Fischer, et al. (1996) measured hydrocarbons found in gasoline in ambient air, indoor air, and soil gas at two depths. They report attenuation coefficients from 4.0×10^{-4} to 1.9×10^{-3}. They also used an SF_6 tracer gas and reported an attenuation coefficient of 2.5×10^{-4} with no forced pressurization. Olson and Corsi (2001) used an SF_6 tracer at two houses in New Jersey and reported attenuation coefficients ranging from 5.52×10^{-5} to 1.7×10^{-4}. Johnson, et al. (1999) suggested an upper limit of about 1×10^{-3} for α. Elsewhere, Johnson (2002) suggested a reasonable range for α of 1×10^{-4} to 1×10^{-2} for screening purposes. Our data show a lower α than of these published values. This is significant given that the gas-phase contamination was present immediately beneath the building slab and the building slab is relatively thin and old.

The absolute concentrations of PCE measured in this study are high relative to typical indoor air concentrations in houses and offices, which are reported to be 0.14 and 0.47 ppbv, respectively (Hodgson and Levin, 2003). The measured values are not high, however, compared with measurements made in apartments or condominiums located in the same building as dry cleaners. PCE values up to 197,000 μg/m^3 have been reported, with median values well above 1,000 μg/m^3 in several studies (US EPA, 1998).

The air exchange rate for buildings varies widely. The US EPA (1997) evaluated data from several thousand houses and found a geometric mean of 0.46 ACH with a 90th percentile value of 1.26 ACH. Office buildings typically are designed to have 15 cfm per person of ventilation, which results in a value of about 1 ACH. The US EPA (Persily and Gorfain, 2004) measured ventilation at 369 office buildings and found a median of 0.98 ACH. Slightly higher ventilation rates per person are recommended for restaurants, which yields design values of roughly 5 ACH given the higher density of persons in restaurants compared with offices. Measurement data for restaurants are relatively limited. One study of nine Florida restaurants reported an average of 3.8 ACH (Cummings, et al., 1997). The measured values of 1 to 2 ACH at the Grand Plaza site appear to be relatively low for a restaurant, but are much higher than the default value of 0.25 ACH in the US EPA November 2002 guidance, which is based on the 10th percentile for single residence buildings.

Assuming a steady-state mass balance, the emission rate of PCE into the building was 0.086 g/hr based on a ventilation rate of 1.9 ACH and the concurrent indoor air measurement. Q_{soil} = 0.082 L/min based on the "hot spot" PCE concentration of 0.26%. The total volume of soil gas entering the building is almost certainly higher than this value, which represents only the rate of contaminated soil gas entering the building. EPA's default value for soil-gas infiltration is 5 L/min for a residential structure with a 100m^2 footprint. Normalizing the Grand Plaza value to this footprint yields Q_{soil} = 0.044 L/min, which is 0.9% of the EPA default value.

The inhalation unit risk (IUR) for PCE is usually given as 3.0E-06 per ug/m^3. For a 1×10^{-5} risk, the resulting concentration is $0.00001/3.0 \times 10^{-6} = 3.33$ μg/m^3. This number reflects a continuous 70-yr exposure and is then adjusted for the assumed exposure scenario. If the usual occupational exposure scenario of 8 hr/day, 5 day/week, 50 week/yr for 25 years is assumed, the 1×10^{-5} risk level is 41 μg/m^3. Therefore, average measured value of PCE at this site yields an estimated risk of 2×10^{-5}. Risks above 1×10^{-4} generally are considered unacceptable and risks below 1×10^{-6} are considered to be insignificant. The assumed exposure scenario is conservative for this site given the turnover of businesses at this location.

The installation of a sub-slab depressurization system for this site was considered and a design was prepared. There is, however, no regulatory requirement for such a system. Representatives from the City of Dallas, with input from TCEQ, elected not to install a system at this time. It is recognized that controls would be required in some other jurisdictions based on the measured concentrations of VOCs, such as PCE, in the indoor air and/or in the sub-slab soil gas.

The results for this site have several implications for the standard regulatory approach for evaluating vapor intrusion. One, field investigations at sites with surface releases should include measurements in surface soil layers. Groundwater, soil, and soil-gas measurements at depth may not identify the maximum concentrations present at the site. This study illustrates the extreme spatial variability sometimes found in the subsurface at contaminated sites. Two, the use of mean values instead of maximum values may still be very conservative when soil-gas measurements are used to estimate indoor air concentrations using an α of 0.1 or 0.02. Three, the US EPA defaults for parameters such as Q_{soil}, Q_{Bldg}, and ΔP may be very conservative for a given site. Site-specific measurements can readily be performed to provide more accurate estimates for these parameters instead of relying on default values.

SECTION 6
SPECIFICATIONS FOR CONTROL SYSTEM FOR GRAND PLAZA SITE

6.1 Location

These specifications are for the installation of an active soil depressurization systems at the Grand Plaza site. As discussed elsewhere in this report, it was ultimately decided not to install the system at this time.

6.2 Site Specific Conditions

These specifications are based upon a limited investigation of the site and therefore certain installation details will need to be verified by the installer at the time of bid or installation, as follows:

- The discharge of the system is to be at least 10 feet (3m) from any air intakes or openings into to the building, including those which are mounted on the roof (roof access was not available during inspection). If the locations indicated for the systems does not allow for this separation, the discharge points may be rerouted to allow for such a separation.
- The suction point locations may be within plus or minus 2 feet (0.6 m) from the locations indicated on the drawings to allow for interference avoidance.
- Underground and underslab utility lines were not definitively located during investigation. Contractor to request such locates by the local utility company, with specific attention to the potential location of a gas line near the location of the chicken fryer.
- Contractor to prime and paint all exterior and exposed components of the system using a primer and paint color acceptable to the client.
- Installation to be done in a manner that does not interfere with the operation of the business within the unit that these systems are to be installed upon.
- Two active soil depressurizations are called out. Each system is to be independent of the other. At the option of the client, these systems may be installed concurrently or sequentially as dictated within the request for bid documentation.
- System to be installed in accordance with US EPA Radon mitigation Standards EPA 402-R-93-078, October 1993 (Revised April 1994) available at http://www.epa.gov/radon/pubs/mitstds.html.
- These specifications are provided as guidance for installation. Where there is a conflict between these specifications and local building codes, the local building codes shall prevail. Furthermore, the competency of the contractor is one of the basis for selection and therefore it is expected that if the contractor will identify interferences or more optimal approaches and make appropriate suggestions to the client in a manner that does not conflict with the intent of the system.
- It is assumed that any building permits shall be obtained by the contractor as needed for this work in accordance with local regulations.
- It is also assumed that any air pollution permits that may be needed for this system(s) shall be the responsibility of the client, rather than the contractor.
- Fan location and enclosures: It is suggested that the fans and their enclosures be located as close to the roofline as possible to avoid impact of exterior parking space. Consequently, it is suggested that the fan enclosures be inverted to allow for vent piping to be as close to the wall as possible.
- Where asphalt must be removed for installation of suction points, the asphalt shall be repaired.

6.3. Active Soil Depressurization System

The systems to be installed shall be designed to extract soil gases from beneath the foundation and exhaust them to a location above the roofline of the.

structure and at a location where soil gases will not re-enter the building

6.3.1 Depressurization Fan

Fans to be capable of delivering a minimum of 190 cubic feet per minute (5.4 m^3/min) at 1.0 inches (2.5 cm) of water column differential pressure. Fans to be rated for exterior use in a hot, humid climate, as will as conveyance of moist, non-combustible air.

- Fan systems to be: PDS MI 220 system as manufactured by professional Discount Supply (www.pdsradon.com) matched with Fantech HP-220 fan, or approved equivalent.
- Fans casings to have 6-inch (15 cm) intake and discharges
- Power: 120 volt, 60 Hz, 150 watt
- Fan to be matched with performance indicator to provide indication of current draw as a means to indicate continued fan operation.
- Number required: two (2)

Fan Power Supply

Electrical power is to be routed to the indicator panel and fan in accordance with the local electrical codes and in conformance with the existing electrical service within the subject building.

Power for the system indicator is to be supplied from the same circuit that supplies power for the fan.

Existing circuits may be utilized, if the addition of the system in addition to current use would not exceed 80% of the circuit capacity.

Fan Orientation and Connection

- Fan shall be positioned in the vent pipe system in a vertical manner.
- Fan is to be secured to the vent pipe system on both inlet and outlet connections with flexible connectors secured by stainless steel hose clamps to facilitate removal.
- Fans shall not be glued or otherwise permanently attached to the pipe system.

Fan Enclosure

The fan is to be housed in an enclosure designed to protect it from wind and physical abuse. Enclosure is to consist of a wall mounted base plate and cover. Material of construction is to be water-resistant ABS plastic. Fan enclosure to be FH-89 fan housing as manufactured by RCI, 511 Industrial Drive, Carmel Indiana (317) 846-7486 or approved equivalent. Enclosure is to be primed and painted with two coats of cover in a color to match the exterior color scheme as is reasonably achievable.

System Performance Indicator

- Each system will have a performance indicator mounted as indicated in the Figures.
- Indicator to be as specified in Section 6.3.1.
- Electrical power for the system indicator is to be supplied from the same circuit that supplies power for the fan. Power to be routed in compliance with local electrical codes.
- Affixed to the power indicator shall be a label detailing the system ID number (i.e., SP-l, SP-2, etc.). The number of the circuit breaker providing power to the ASD system and the panel ID # is to be written on inside of performance indicator box.
- Indicator to be adjusted to "Green" zone after fan has been activated and system installation is complete. Power draw is also to be measured (current x voltage) and provided to client at conclusion of work.

6.3.2 Pipe and Fittings

Vent pipe to be as follows:

Construction	PVC or ABS ASTM D-1785
Size	4-inch nominal
Schedule:	80
Primed and painted?	Yes
Fittings	Solvent welded (except mechanical connection to fan

Routing

In addition to normal practices for running plumbing lines as though it were soil vents, the pipe shall not be configured such that there would be any accumulation of moisture within pipe. Pipe to have a positive slope back to the suction point of no less than 1/8 - inch per foot (0.3 cm per 30 cm).

Pipe Supports

Pipe supports shall be used to secure the piping system. At a minimum pipe supports shall be applied every 2 meters in vertical runs and every 1.5-meter in horizontal runs. Pipe supports are to be applied as noted on the drawings with a minimum of pipe supports near the suction point and at the discharge, with the fan being independently supported within the enclosure.

All pipe supports are to be made of non-corrosive material such as stainless steel or galvanized steel. Pipe supports to be a channel and clamp system such as Unistrut or approved equivalent.

Vent Discharge

Location

The discharge of the system shall be oriented either vertically or at a 45-degree angle away from the building and in a location where the discharged gasses may not enter any building or adjacent building openings. In addition to this, the discharge shall be:

- At least 10 feet (3 m) above exterior grade
- At least 10 feet (3 m) away from a passive opening into the building that is less than 2 feet or 60 cm below the exhaust point as measured on a horizontal plane, and 25 feet (7.6 m) away from active air intakes for building mechanical systems.
- At least 10 feet (3 m) from any opening into an adjacent building or public access or easement.

Note that the distance requirements from the point of discharge to the building opening or mechanical system intake is to be measured either directly between the two points or to be the sum of measurements made around intervening obstacles such as building corners.

Discharge Screen

A screen constructed of stainless steel or galvanized metal shall be installed in the discharge after the system has been activated for at least five minutes to clear any residual debris. See Figures.

A UV and weather resistant label shall be affixed to the discharge pipe reading: *CAUTION Soil Gas Vent - Do not tamper or disturb.*

6.3.3 Suction Point

The suction point is to be installed as depicted in the Figures, with the following additional comments:

- Prior to coring holes through concrete surfaces, a rebar locator for ferrous materials is to be used to locate a pathway where rebar will not be cut or there will be a minimal impact. Where re-bar is nicked or cut, the exposed portion of the re-bar is to be protected by a material designed to prevent corrosion of rebar, such as 3M Scotchkote 4l3/2l5/PC or approved equivalent.
- A minimum of 1.5 cubic feet (42 L) of soil is to be dug out from suction point, beneath the slab. Excavation should be upwards to the bottom of the slab to preclude of soil from falling into suction point.
- Suction point piping to be well sealed to inside of concrete core as indicated in the figure to assure an airtight seal.
- A rigid pipe support is to be installed as close to the suction point as possible to maintain the integrity of the seal.

6.3.4 Sealing

Backer Rod and Sealing of Suction Point

Where suction piping penetrates a wall, a positive seal is to be made that is also flexible. A minimum of 2 wraps of closed cell backer rod, is to be used and of sufficient diameter to provide a compression fit between the inside of the core and the outside of the pipe. External portion of connection to have an elastomeric polyurethane caulk, such as Sonolastic NP-I, Geocel21O0 or approved equivalent and is to be applied to a minimum depth of 1-inch.

Caulking Concrete

Efforts shall be made to identify leak points where either interior or exterior air is being drawn down to the sub-grade due to the negative pressures created by the ASD system. This can be identified by non-thermal smoke. Said openings are to be caulked using an elastomeric polyurethane such as Sonolastic NP-l, Geocel 2100 or approved equivalent.

6.3.5 Asbestos Containing Materials

Contractor is to take appropriate precautions when drilling through building materials that may be suspected of containing asbestos. If any suspected asbestos containing materials are encountered, the material is not be disturbed and the client is to be notified, prior to continuing work that would disturb suspected asbestos containing material.

6.3.6 Excavation and Repair

Where excavation and or demolition is required the area is to be secured and appropriate safety measures are to be taken both during and after hours to protect the public.

Where excavation or demolition of concrete sidewalks, planters, tile, etc. is required, said area is to be restored as close as reasonably possible to its original condition.

6.3.7 Painting

All pipe, fan shroud covers, conduit, etc. shall be painted to match exterior color scheme. Plastic components are to be primed with an appropriate primer for the base material to be painted. A sufficient number of surface coatings are to be applied to fully cover the component. All system components will be painted in accordance with client specifications.

6.3.8 Labeling Requirements

Labels listed below are to be of suitable material for environment they will be located. Labels located outdoors are to be resistant to UV and weather damage.

ASD System
At least one label shall be affixed to the mitigation system in all locations where vent pipe is visible. Label is to read: *CAUTION Soil Gas Vent - Do not tamper or disturb.*

Circuit breaker
The circuit within the building power panel from which the ASD fan power supply is obtained is to be labeled "Soil Vent System".

Performance Indicator
The number of the circuit breaker providing power to the ASD system is to be labeled on inside of each performance indicator box.

6.4 Figures and Details

The following non-scaled figures and details are provided as guidances for installation:

Figure 6-1:	Installation Schematic
Figure 6-2:	Location of Suction Points
Figure 6-3:	Pictorial Indication of System Locations & Details
Figure 6-4:	Detail 1 Suction Pit
Figure 6-5:	Detail 2 Vent Discharge

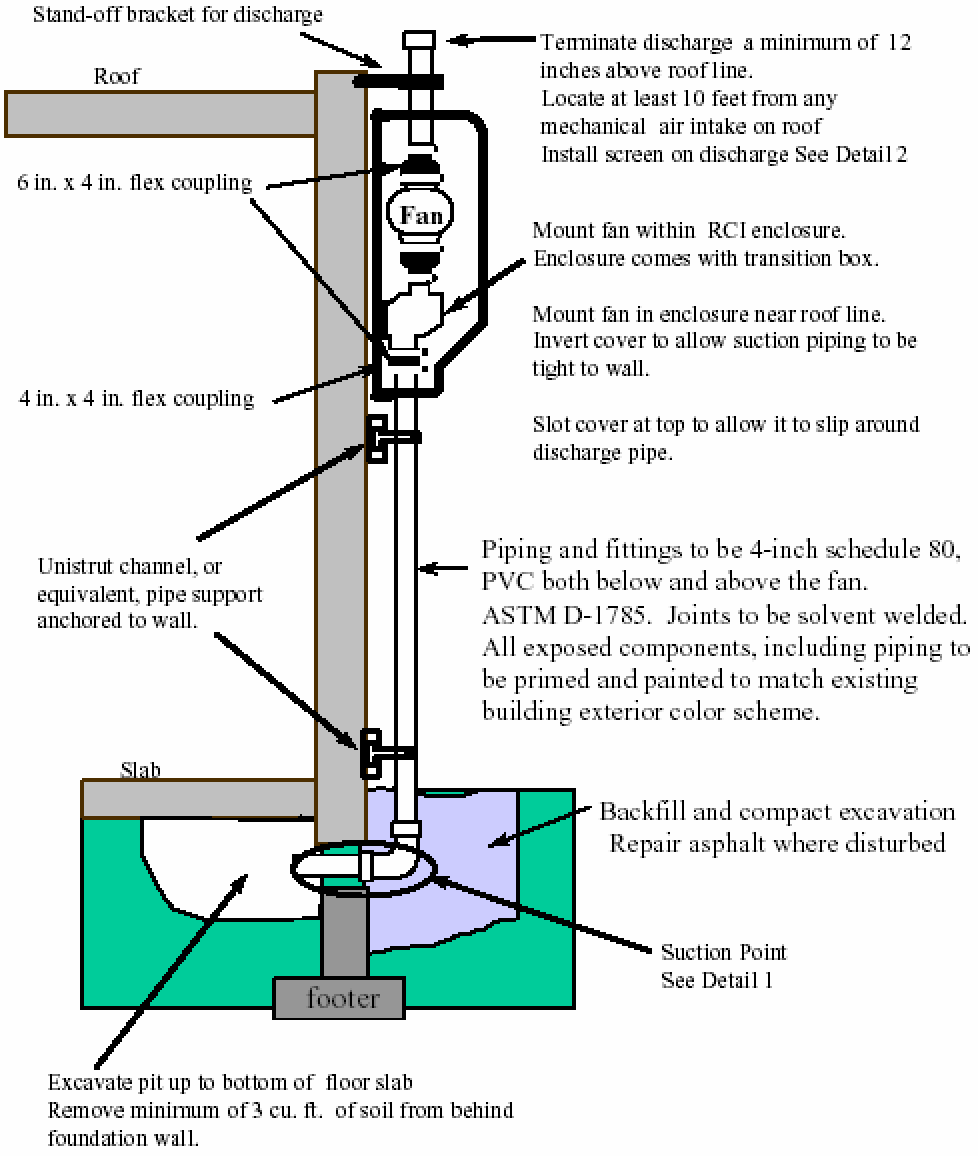


Figure 6-1. Installation Schematic

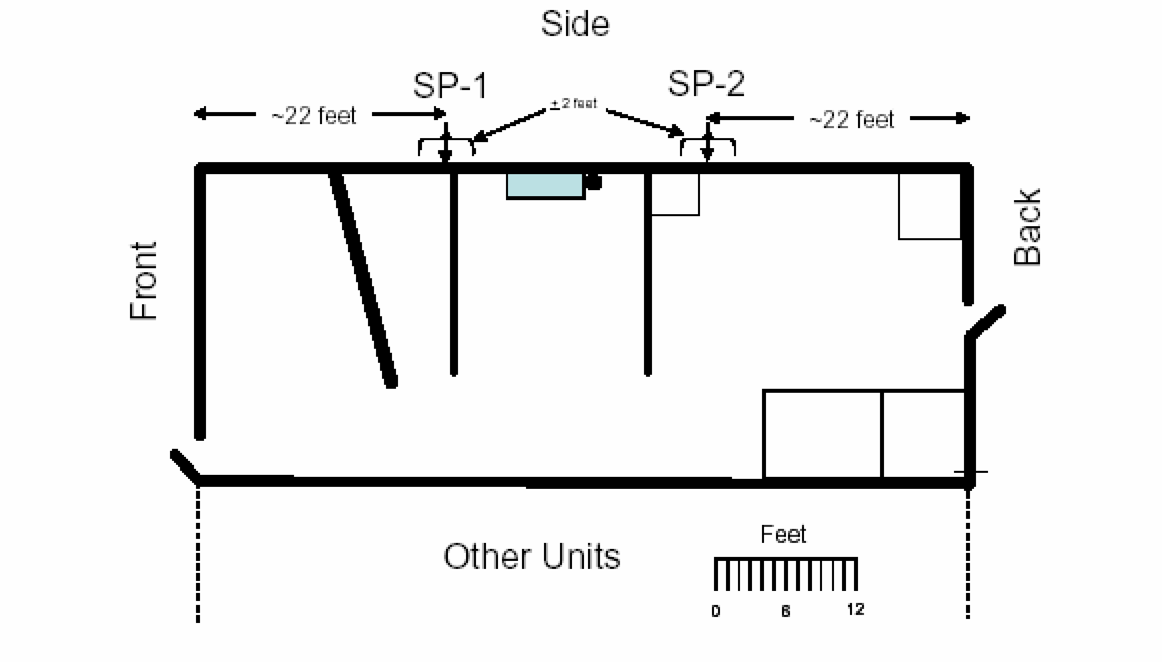
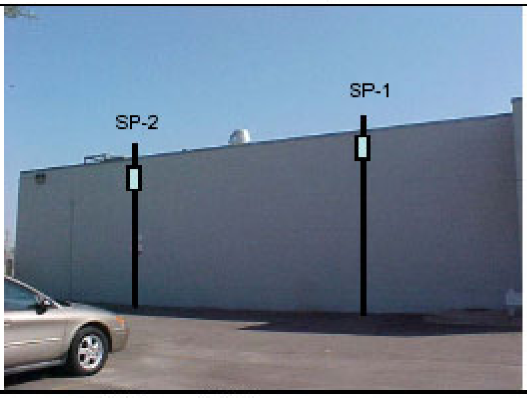


Figure 6-2. Location of Suction Points



- Locate fan systems up high on building.
- Piping to be schedule 80 PVC for durability.
- Horizontal cores through foundation wall.
- Asphalt to be cut to allow access for core rigs and replaced.
- Pipe and shroud to be primed and painted.
- Suction point locations can be moved 2 feet either direction from point noted to avoid obstructions.
- Discharge points to be 10 feet from roof top air intakes.

	▪ Core horizontally through foundation wall. ▪ Avoid re-bar-patch if nicked or damaged. ▪ Patch asphalt, if disturbed. ▪ Location can be + 2 feet from specified location
	▪ Locate performance indicators on wall adjacent to circuit panel. ▪ Utilize existing circuit if not overloaded, otherwise install new circuit (fans rated for 150 watts each).
	System Performance Indicator ▪ One per fan ▪ Could be mounted externally if desired. ▪ Matched to fan ▪ See specifications

Figure 6-3. Pictorial Indication of System Locations and Details

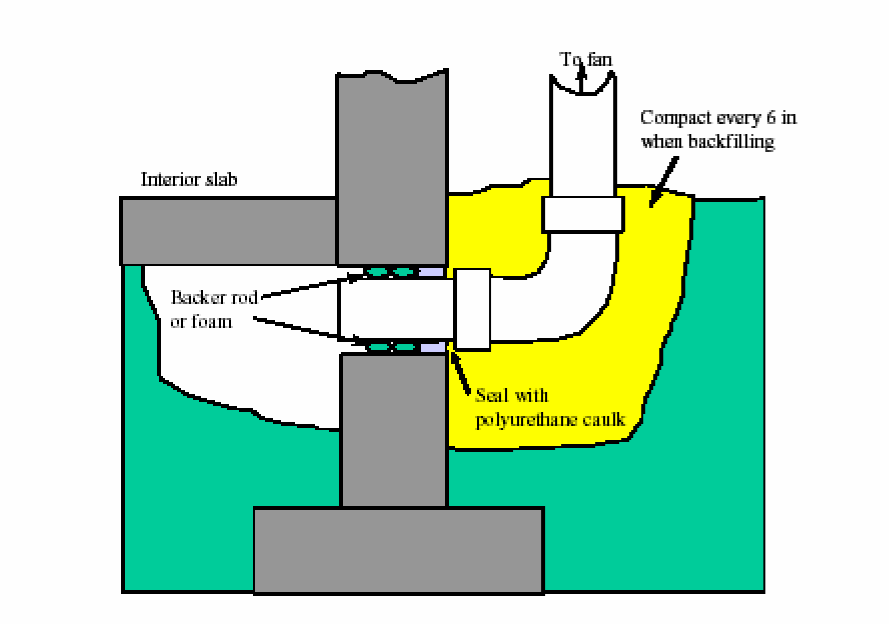


Figure 6-4. Detail 1 Suction Pit

Notes:

- Location of core should be such that upper edge of hole is as close as possible to the bottom of the slab. Excavate if necessary.
- Locate in accordance with general location shown on plan drawing, avoiding
- sub grade utilities (call for utility locates and applicable digging permits)
- Use core bit to cut hole - Do not chip out. Core 6-inch diameter hole through concrete wall.
- Use re-bar locator to avoid rebar where possible. REPAIR KNICKED OR DAMAGED REBAR with 3M Scothkote 413/215 PC or equivalent.
- Excavate out a minimum of 1.5 cu. ft. of soil. Soil must be removed up to underside of slab.
- Insert vent pipe through hole extending at least 2 inches into excavated pit.
- Seal pipe to inside of core with a minimum of two wraps of 1-inch backer rod. Seal outer portion of pipe to wall with polyurethane caulk with a minimum depth of 1inch.
- Back fill hole, stopping at 6 in depths to compact soil.
- Replace asphalt where it was removed to facilitate coring of wall.

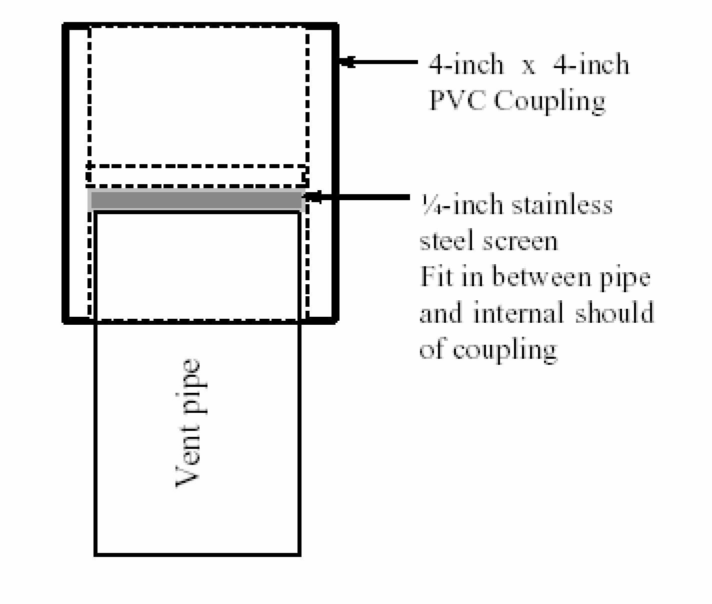


Figure 6-5. Detail 2 Vent Discharge

SECTION 7
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