

# **DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM**

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# **An Evaluation of Volatile Organic Compound Contamination at Two Superfund Sites**

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## ABSTRACT

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Volatile chemicals have the potential to migrate from contaminated soil and groundwater plumes into buildings. The vapors may enter through openings in basements, foundations, sewer systems, and utility lines. Exposure to volatile organic compounds (VOCs) in the form of vapor intrusion may cause a series of adverse health effects depending on the type of chemicals, the concentrations, the length of exposure, and the individual. This project consists of performing a study of VOC contamination, specifically trichloroethene (TCE), at two Superfund sites; Industrial Site 'P' and Residential Site 'L'. The selected sites are at various stages in the U.S. Environmental Protection Agency (EPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) "Superfund" cleanup process. The cleanup process includes a wide variety of characterization, monitoring, and remediation technologies. The majority of Superfund sites begin the process with preliminary assessment/site inspection, followed by a National Priorities List (NPL) listing. Next comes the remedial investigation/feasibility study (RI/FS), followed by the record of decision (ROD). Where needed, there will be remedial design/remedial action (RD/RA), construction completion, post construction completion (long term remedial action, NPL deletion, and site reuse/redevelopment). Industrial Site 'P' is at the end of the CERCLA Superfund cleanup process while Residential Site 'L' is at the RI/FS stage.

Groundwater potentiometric surface maps were generated based on 2012 groundwater elevation data from individual wells at both Industrial Site 'P' and Residential Site 'L'. Analytical lab data containing VOC concentrations for a series of chemicals have been evaluated to assess which values exceed the EPA's maximum contaminant limits (MCLs). Since TCE is a contaminant of concern (COC) at both Industrial Site 'P' and Residential Site 'L', plume maps were also created to depict the extent of TCE contamination. VOC concentrations prior to (February 2007), during (December 2007, for approximately 3 months after the technology was initiated) and after the implementation of the electrical resistance heating (ERH) system with vapor extraction (VE) were used to generate plume maps for the various Exposition Aquifer hydrostratigraphic zones present at Industrial Site 'P'. In the case of Industrial Site 'L', a plume map was created for the wells screened at a shallow zone (generally less than 100 feet below ground surface) after it was determined that contamination is not common beyond such depth.

Based on the data evaluation, the ERH remediation for Industrial Site 'P' appears to have reduced the overall extent of the TCE plume in all affected hydrostratigraphic zones. Although, TCE and 1,1,1 trichloroethane (TCA) are still present, they do not pose a vapor intrusion problem within the domain of the site. The continued monitoring of groundwater and soil gas vapor at Industrial Site 'L' and in adjacent offsite residential areas is recommended.

At Residential Site 'L', elevated values of TCE, TCA, and other VOCs were observed in the analyzed shallow groundwater samples. Vapor intrusion is of concern at Industrial Site 'L'. This statement is confirmed by results from Residential Site 'L' sub-slab air

sampling. Sub-slab depressurization systems among other technologies are recommended to address the immediate hazards of exposure while the rest of Site 'L' is in the process of being remediated.

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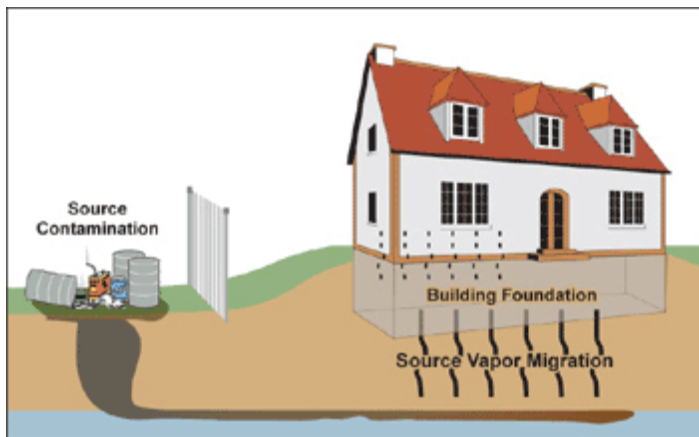
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# 1. INTRODUCTION

Vapor intrusion occurs when a chemical spill transgresses into indoor air. VOCs are chemicals that tend to easily produce vapors. The potential for vapor intrusion is highly dependent upon the site’s geology and the building’s structural integrity as these vapors can easily travel through rock or building fissures (See Figure 1). The EPA defines VOCs



**Figure 1. Conceptual Diagram of Vapor Intrusion**  
 Source: (Treehugger A Discovery Company, 2012)

as any carbon compound that generates considerable photochemical reactivity with the exception of carbon monoxide, carbon dioxide, carbon acid, metallic carbides, and ammonium carbonate. The compound’s chemical composition allows them to volatilize under atmospheric conditions. According to the EPA, VOCs have boiling points

less than or equal to 250 degrees Celsius. VOCs may also be classified as very volatile, volatile, and semi-volatile. The degree of volatility is inversely related to the boiling point of the compound. The table below shows this classification as established by the World Health Organization (WHO, 1989).

**Table 1. VOC Categorization**  
 Source: (WHO, 1989)

Description	Acronym	Boiling Point (*C)
Very volatile (gaseous) organic compounds	VVOC	<0 to 50-100
Volatile organic compounds	VOC	50-100 to 240-260
Semi volatile organic compound	SVOC	240-260 to 380-400

In practice, VOC volatility is measured by standard methods and at times the organic compound may be classified as an SVOC or VOC. VVOC exists in a gaseous phase. VOCs are naturally occurring in liquid form but volatilize quickly when exposed to air. Examples of VOCs include formaldehyde, d-limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal, TCE, and TCA. This report focuses primarily on TCE and TCA due to their past presence at both sites.

TCE has been used industrially as a degreasing agent and as a solvent in dry cleaning since the early 1940’s. It is present in paint removers, strippers, cosmetics, adhesives, typewriter correction fluids, and household cleaners (Collier et al., 2003). In 1989, the EPA established a TCE drinking water standard of 5 µg/L. More conservative standards have been established by some state and local governments. For example, the Indiana



Department of Environmental Management (IDEM) has set the limit at 2 µg/L. TCE is typically flavorless, odorless, and colorless in groundwater for concentrations less than 25,000 parts per billion (ppb). TCA, also known as methyl chloroform, is also used as a degreaser, dry cleaning solvent and in the cleaning of metals. Similarly to TCE, TCA exhibits an odor resembling that of chloroform at concentrations of approximately 120,000 ppb. These VOCs are not detected by most people unless the concentrations are already well beyond the allowable standards.

TCE is known to be carcinogenic in animals and may be potentially carcinogenic in humans. The direct connection between TCE and certain types of cancer remains controversial. In 2003, Collier and Johnson established a connection between the consumption of TCE contaminated water by pregnant women and higher than expected quantity of leukemia occurrences in those children. A 2002 study performed by Costas also revealed a higher risk for childhood leukemia in cases where mothers drank contaminated water while pregnant. A study between 1979 and 1987 in New Jersey monitoring approximately 1.5 million residents also revealed significant numbers of total leukemias, childhood leukemias, acute lymphatic leukemias, and non-Hodgkin's lymphoma in females exposed to greater than 5 µg/L of TCE (Cohen et al. 1994). TCE has been proven to have a series of non-cancerous effects mostly consisting of heart defects in developing embryos. In 2003, Johnson noted placental transfers from mother to fetus as a byproduct of TCE consumption through groundwater. Adults exposed to TCE may also be at a higher risk of developing heart disease.

According to EPA, TCA is a non-carcinogenic VOC. However, it can irritate the skin, eyes, and impact the functions of the cardiovascular system and central nervous system. Acute exposure symptoms include dizziness, drowsiness, and decreased reaction time (ATSDR, 1997).

A list of VOC's and their associated EPA MCLs are shown in Appendix A, Table A-1. Vapor intrusion is typically investigated by collecting soil or groundwater samples near a known spill to determine if there is on-site contamination. If soil vapor or VOCs are detected in the groundwater then indoor sub-slab air sampling is performed in nearby residences and buildings. Sub-slab air samples are also collected and are often better indicators of a vapor intrusion problem since the air in the area is not as exposed to other indoor chemical sources that might corrupt or provide false alarms during the tests. Indoor vapor intrusion readings are typically magnitudes lower than sub-slab results since the gas is trapped within these areas. Soil gas levels are also typically higher than groundwater concentrations (ATSDR 2008). Common solutions to vapor intrusion include the installation of a radon mitigation system through which suction is applied below the foundation and routed to the outside.

### **Industrial Site 'P' Description**

Industrial Site 'P' was a chemical blending facility from the 1940s until 1991. A complaint filed with the Los Angeles County Fire Department, Hazardous Waste Control Department (HWCD) indicated that 400 drums were abandoned onsite along with underground and aboveground storage tanks. The EPA issued a removal action in 1993

subsequent to an abrupt fire that consumed part of the property. In 1997, an EPA Superfund Technical Assessment and Response Team (START) contractor concluded that chlorinated and non-chlorinated VOCs were released and present in the perched aquifer in a 3 to 5 foot thick plume.

Industrial Site ‘P’ was listed on the NPL in 1999, the RI/FS was finalized in 2004 (TN & A, 2004), and the ROD was implemented in 2005 (TN & A, 2005). The selected remedy included remedial action for the surface and near surface soil zone (0–3 ft bgs), upper vadose zone soils and perched groundwater (3-35ft bgs), and lower vadose zone and



**Figure 2. Industrial Site 'P' General Site Map**

Exposition Aquifer groundwater (35-100+ ft bgs) (TN & A, 2005). The surface and near-surface soil remedy included soil cover/re-vegetation.

Contamination at the upper vadose zone and the perched groundwater was addressed via high-vacuum dual-phase extraction (HVDPE) with ultraviolet (UV) oxidation of extracted groundwater, flameless thermal oxidation (FTO) and granular activated carbon (GAC) for treatment of extracted vapors (TN & A,

2005). The lower vadose zone soil and exposition groundwater remediation methods included ERH with vacuum extraction (VE), vacuum-enhanced groundwater extraction, groundwater pumping and treatment, and monitored natural attenuation (MNA); combined with UV oxidation for treatment of extracted groundwater, and FTO, and GAC for treatment of extracted vapors (TN & A, 2005).

The site is located in east Los Angeles County, along the Los Angeles River (SulTRAC 2012). As shown in Figure 1 (detailed map shown in Appendix B, Figure B-1), Slauson Avenue bounds the north side. Residential and industrial properties border the west and south side respectively, while the concrete-lined Los Angeles River lies to the east. The current site encompasses 1.4 acres of land adjacent to a Riverfront Park. The current site is expected to be assimilated into the Riverfront Park adjacent to the project area once it is remediated. The site was originally 4 acres; 2.6 acres have been remediated and converted to an industrial park. Remediation solutions and monitoring efforts continue to be implemented in the remaining 1.4 acres.

**Geology & Hydrogeology**

The topography of Industrial Site ‘P’ is relatively flat. Dominant geologic units beneath the site include the Holocene Recent Alluvium, the Pleistocene Lakewood Alluvium, and the Lower Pleistocene San Pedro Formation. These are described in greater detail in the

2010 Monitoring and Sampling Report for the site. The Exposition and Gage/Gardena Aquifer are located within the Lakewood Formation.

The Hollydale, Jefferson, Lynwood, and Silverado Aquifers, made up of a various lithologic deposits from marine and terrestrial environments, are part of the San Pedro Formation. The Jefferson and Hollydale Aquifers are used for municipal and industrial sources of water with production wells screened at depths of greater than or equal to 350 ft bgs about a half-mile south of Industrial Site 'P'. Six saturated zones consisting of the Perched and Exposition Zones 'A' through 'E' lie beneath the Site. Zones 'A' through 'E' do not represent a viable source of water in terms of yield. These zones are stratified as follows:

- The perched zone, between 25 and 40 ft bgs, is characterized by an irregular top surface of Perching Clay with low transmissivity and limited yield. Groundwater is present in discontinuous lenses and variable as observed from past groundwater gradients. In general, flow direction within this zone is towards the south.
- Exposition Zone 'A' is characterized as a series of semi-discontinuous saturated sand lenses. It is located between 75-80 ft bgs and ranges from 3 inches to 10 feet in thickness. The saturated thickness of this layer is between 0 to 12 inches.
- Exposition Zone 'B' occurs approximately from 80 to 90 ft bgs. It is typically 0 to 5 feet in saturated thickness.
- Zone 'C' occurs between 95 to 110 ft bgs. The saturated zone is 0 to 10 feet in thickness.
- Zone 'D' and 'E' occur from 124 to 145 ft and 160 to 175 ft bgs respectively (U.S. E.P.A., 2010). The saturated part of the 'D' Zone is typically 10 to 21 feet in thickness while Zone 'E' is usually fully saturated.

The surface and near-surface soil within the site and surrounding area is characterized by a surface fill varying in thickness from 2 to 6 feet and composed of dark yellowish-brown silty sands and local gravelly sands or clayey gravels. The vadose zone at the site is subdivided into the Upper Vadose Zone and the Lower Vadose Zone due to their distinct features. The Upper Vadose Zone includes sand and perching clay. The sand is typically 2 to 25 feet bgs and 1 to 20 feet in thickness. The perching clay can be found between 28 to 40 feet bgs and ranges from 10 to 20 feet in thickness. Discontinuous sandy silt and lean clay lenses ranging from 3 inches to 4 feet in thickness are present in the Upper Vadose Zone. An upper sand unit and a lower fine-grained unit are found in the Lower Vadose Zone. The upper sand unit typically located between 40 and 50 ft bgs is usually 1 to 40 feet in thickness. This zone; characterized by medium-grained poorly graded sands to gravelly well-graded sands, generally becomes coarser downward with poorly graded gravel basal units. The Lower Vadose Zone upper sand unit is usually 1 to 14 feet thick with local intervals of silty sands and poorly graded sands.

## Residential Site 'L' Description

Groundwater contamination at Industrial Site 'L' became a concern in the late 1980's when Indiana's Health Department found elevated levels of TCE (trichloroethylene), and 1,1,1-TCA (1,1,1-trichloroethane) in private drinking water wells. Municipal water connections and water filters were installed for several residences that at the time were



**Figure 3. Residential Site 'L' General Site Map**

dependent on private wells for drinking water. Additional sampling in 2006 revealed that 12 additional wells were exceeding the drinking water levels for chlorinated solvents. In 2008, the site was placed on the NPL. A ground-water plume consisting primarily of chlorinated solvents including hazardous chemicals such as TCA, TCE, DCE and other chlorinated compounds is known to exist within the boundaries of Residential Site 'L'. This 870 acres site encompasses a population of approximately 2600. It is bounded as shown in the figure by a Meandering River on the north, on the west by State Road, on the south by H Avenue, and on the east by O Avenue. The site is divided into the north and south portions by a railroad. Being in the early stages of RI activities, the source, vertical extent of contamination and number of residences impacted by vapor intrusion is in the process of being characterized and delineated.

Residents within the site obtain their water either from the city or private wells. A total of 20 of the 94 private wells within the site are or have been contaminated and exhibit or exhibited elevated levels of chlorinated solvents throughout various sampling events since the 1980's. Industrial and commercial activities within the site include "the manufacture of pharmaceuticals, recreational vehicles, mobile and modular homes, band instruments (such as woodwinds), tape, corrugated containers, foam and plastic products, metal fabricating and scrapping, auto salvage and repair, plating, lumber-yard activities, and a former dump" (ATSDR, 2009).

### Geology & Hydrogeology

The Meandering River bordering the northern portion of the site flows from east to west towards Lake Michigan. Groundwater at the southern portion of the site is estimated to be 20 feet bgs and the water table becomes shallower in a northward direction where it discharges to the river (0 ft bgs). Underlying the site is the St. Joseph Aquifer. The unconfined surficial aquifer is easily susceptible to contamination due to its high permeability and the ease through which contaminants are transported in the predominantly sand and gravel layers. A shale bedrock confining unit is present approximately at a depth of 150 to 200 feet bgs (ATSDR, 2009). A confining layer of silt

and clay is present in some portions of the site separating the aquifer into an upper and lower water bearing zones.

## 2. EXECUTIVE SUMMARY

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This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2012, a DOE Fellow intern (Lilian Marrero) spent 10 weeks doing a summer internship at Sullivan International Inc. under the supervision and guidance of Dr. Jennifer Knoepfle. The intern's project was initiated on June 4, 2012, and continued through August 10, 2012 with the objective of collecting data from numerous sampling events for Industrial Site "P" and Residential Site "L" with the purpose of determining which VOC's are present in the groundwater and ultimately determining if there are vapor intrusion problems. Minor objectives include understanding groundwater flow patterns, identifying VOC's in excess of regulated standards, generating contaminant plume diagrams, and proposing mitigation technologies for cases where vapor intrusion was determined to be an issue.

### 3. RESEARCH DESCRIPTION

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Data has been collected from numerous sampling events for Industrial Site ‘P’ and Residential Site ‘L’ with the purpose of determining which VOC’s are present in the groundwater and ultimately determining if there are vapor intrusion problems. Minor objectives include the following:

- Obtain an understanding of the groundwater flow patterns.
- Identify VOCs exceeding regulated standards.
- Generate contaminant plume diagrams.
- Propose mitigation technologies if vapor intrusion is determined to be an issue.

#### Industrial Site ‘P’

At Industrial Site ‘P’, the selected remedy involved high-vacuum dual-phase extraction (HVDPE), ERH with VE, and groundwater pump and treat systems implemented in 2007. The ERH with VE ran for a distinct (3 month) period of time in 2007. Currently, the HVDPE and groundwater pump and treat are still operating at Industrial Site ‘P’.

Groundwater VOC data was evaluated from the wells listed below for pre-ERH 2007, post-ERH 2007, and 2012 at the Industrial Site ‘P’. The pre-ERH 2007 data served as a baseline from which any changes in VOC concentrations due to the selected ERH remedy were assessed. Additionally, groundwater elevations, potentiometric surface maps and TCE plume maps were created for these time period to understand site Hydrogeology and its impact on the contaminants.

Six distinct groundwater zones stratigraphically equivalent to the Exposition Aquifer exist beneath the Industrial Site ‘P’. These include the perched zone, 30–35 ft below ground surface (bgs) and Exposition Zones ‘A’ through ‘E’. Exposition Zone ‘A’ ranges between 75-80 ft bgs. It is followed by Exposition Zone ‘B’ from 80 to 90 ft bgs. Zone ‘C’ occurs between 95 to 110 ft bgs. Zone ‘D’ and ‘E’ occur from 124 to 145 ft and 160 to 175 ft bgs respectively (U.S. E.P.A., 2010). TCE plume maps were developed for each zone along with chemical of concern (COC) box plots.

**Table 2. Groundwater Monitoring and Extraction Wells at Industrial Site ‘P’**

<b>Well ID</b>	<b>ZONE</b>	<b>Well ID</b>	<b>ZONE</b>	<b>Well ID</b>	<b>ZONE</b>	<b>Well ID</b>	<b>ZONE</b>
PB-01	Perched	MW-21-90	B	MW-24-110	C	MW-24-140	D
PB-02	Perched	MW-20-85	B	MW-25-110	C	MW-12-150	D
PB-05	Perched	MW-12-90	B	MW-05-105	C	MW-23-145	D
PB-07	Perched	MW-26-90	B	MW-23-110	C	MW-05-135	D
DA-02	Perched	MW-06-85	B			MW-25-130	D
DA-06	Perched						
DB-06	Perched						
DB-04	Perched						

## **Residential Site ‘L’**

Residential Site “L” groundwater contamination is present in the form of a large area-wide tear-drop shaped plume. The COCs are chlorinated solvents (U.S. EPA, 2008). In January of 2011, EPA contractors began installing monitoring wells to test the groundwater for VOC contamination. EPA is currently requesting access to approximately 44 residencies to investigate if vapors and gases migrating from the groundwater are entering indoor space while simultaneously performing the sub-slab test for those households that have granted access (U.S. EPA, 2012). The laboratory data from the vapor intrusion sampling events were processed, and analyzed to determine the concentrations of VOCs present. The data were further evaluated to assess whether TCE concentrations were in excess of EPA criteria. Similar to Industrial Site ‘P’, groundwater potentiometric surface maps and TCE plume maps were deemed applicable and COC analytical plots were developed for Industrial Site ‘P’. Based on the data analysis, if vapor intrusion is determined to be a threat at Residential Site ‘L’, then mitigation technologies for vapor intrusion will be recommended with the intent of minimizing to acceptable limits or completely eliminating human exposure to anthropogenic soil and groundwater contaminants. Excel spreadsheets and Geographic Information System (GIS) were used to analyze and convey the interpreted data respectively.

### **Groundwater Potentiometric Map Creation**

The general approach taken in developing groundwater potentiometric maps (i.e. contours) includes the following:

- Create spreadsheets with groundwater elevations for monitoring wells.
- Create a layer in GIS for each aquifer zone, and adding the well coordinates and groundwater elevations to the attribute table in GIS.
- Draw groundwater contours based on field depth to water measurements and calculated elevations (in spreadsheet), performing quality assurance/quality control (QA/QC) on all maps with each respective project manager.
- Geo-referencing the final hand-drawn contours in GIS, sketching the contours as graphics, converting the graphics to feature class, adding it to the site as a layer, and ultimately creating a Geo-Database for the contours.

### **Evaluation of Analytical Data**

The following procedure was implemented in evaluating the analytical VOC data:

- Ensure that all laboratory data were validated and passed internal QA/QC standards by scanning data validation reports and discussions with the project chemists.
- Identifying EPA’s MCLs for each VOC tested, along with any other regional or local VOC limits that may be applicable to the site. For example, in the case of Industrial Site ‘P’, specific regional screening levels were established by the ROD and included when screening the values. For Industrial Site ‘L’, IDEM has more conservative



limits than EPA. These regulations were considered for tap water and indoor air.

- Generating an excel spreadsheet summarizing the analytical lab data, the undetected VOC concentration samples were disregarded, detected VOC concentrations were compared to the most conservative limits from the lists previously mentioned.
- Analytical COC Plots were developed for the detected VOC's.
- A comparison of TCA and TCE data from October 2011 and 2012 was made in Excel for Residential Site 'L' to determine if these concentrations were increasing, decreasing, or staying relatively stagnant.
- TCE concentrations pre-, during, and post- the implementation of ERH were compared in an Excel spreadsheet. Similarly to the process undertaken for the groundwater contours, the information was used to generate contamination plumes in GIS by adding the data as a field, geo-referencing the plumes to the site, creating the feature classes for the plumes, and adding it the database.

Sub-slab gas data was collected at the field, processed by the sub-contracted lab. The analytical data was then compared in Excel to the limits.

## 4. RESULTS AND ANALYSIS

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### Industrial Site 'P'

A combined total of approximately 137 monitoring and extraction wells are present within the domain and surrounding area of Industrial Site 'P' (See Appendix A, Table A-3). This section presents an analysis of groundwater data collected from the Perched and Exposition Zones 'A'-'D'. The data includes groundwater elevations, and VOC concentrations collected during an April and October 2007 and May 2012 field sampling events (Table A-3 through Table A-5 in Appendix A). Results are listed in Table A-4 and A-5. Refer to Table A-3 for well depths. Certain wells were excluded from the data set due to lack of access and/or data availability (dry well). Data from the previously mentioned well series were also analyzed to assess the general trend in COC VOC concentrations within the site.

### Groundwater Contours for 2012

The natural hydraulic gradients at the site were estimated based on monitoring and extraction well measurements. The extraction wells included were not pumping and as such did not influence the groundwater levels. The following well series were used to develop groundwater contour maps for 2012:

- Well series B-01 through B-39 within the perched zone (except B-02, B-05 through B-09, B-11 through B-16, B-23 through B-29, B-33 through B-37), PA-03, PA-05, PB-01 through PB-07 (except PB-02 and PB-06), PC-05 through PC-06, PD-04 through PD-09, SV-1 and SV-05 were considered.
- Groundwater elevations from well series DA-02 through DA-12 (except DA-07) were used to develop groundwater contour maps within Exposition Zone 'A'. Data from MW-04-75, MW-07-75, MW-09-70, MW-10-75, MW-12-70, MW-14-80, MW-21-80, MW-20-75, MW-26-75, and MW-27-70 was also included.
- DAB-01 through DAB-08, and DB-01 through DB-12 (except DB-02), MW-2 through MW-14 at a depth between 85 ft and 95 ft bgs (except MW-07 and MW-11), MW-19 through MW-22, MW-26 through MW-33 (except MW-29), and RW-01.
- MW-05-105, MW-10-110, MW-11-100, MW-23-110 through MW-25-110, and MW-34-110 provided groundwater elevations data for contour maps in Zone 'C'.
- Groundwater contour maps for Zone 'D' included data from MW-05, MW-07, MW-12, MW-130, MW-23, MW-24, and MW-25 screened between 130 ft and 140 ft bgs. Refer to Appendix B for details.

The figures in Appendix B show groundwater elevation data as a potentiometric surface for each zone. Groundwater elevation and flow patterns for the Perched Zone, Exposition Zone 'A', Exposition Zone 'B', Exposition Zone 'C', and Exposition Zones 'D' are discussed below.

- **Perched Zone:** The groundwater flow within the perched zone occurs in various directions throughout the site (see Figure B-2 and B-3, Appendix B). This is consistent with the discontinuous layers exhibited in this zone. The northeastern portion of the site flows in a southeastern direction towards the river. The area covering the River Front Park follows a similar pattern with more of a southward tilt in flow. Groundwater contours for the area by E 59<sup>th</sup> Place and Walker Avenue reveals a southwestern flow away from the river. Groundwater elevations do not change as abruptly within this area.
- **Exposition Zone ‘A’:** The groundwater flow; within the domain of Industrial Site ‘P’ at Exposition Zone A, reveals a trend in the northwest direction away from the Los Angeles River (see Figure B-4). This is not indicative of recharge by the concrete lined Los Angeles River. Instead, it may be attributed to the shutdown of certain pumping wells within the site. The trend in the western residential area adjacent to the industrial site reveals a southeast flow parallel to the river. This finding is consistent with the groundwater contours reported in 2010 Sampling Report for the area (SulTRAC 2010).
- **Exposition Zone ‘B’:** The groundwater elevations and potentiometric surfaces are presented on Figure B-5, also shows the groundwater flowing in a northwest direction, away from the Los Angeles River.
- **Exposition Zone ‘C’:** The January groundwater elevations and potentiometric surface are presented on Figure B-6, which show semi-radial groundwater flow away from monitoring well MW-25-110. As expected the gradient in this deeper zone is much smaller than the zones previously mentioned. A vertical drop in groundwater elevation of 0.5ft is observed in a span of approximately 600 ft. This may be indicative of a slower migration of groundwater in a southwestern direction.
- **Exposition Zone ‘D’:** The ‘D’ Zone groundwater elevations and potentiometric surface are presented on Figure B-7, which shows the groundwater flowing to the southeast almost parallel to the river. Zone E is not accounted for in the study due to the lack of available data for the zone.

### **VOC Groundwater Data Analysis**

Analytical data from February 2007 pre-ERH, December 2007 during ERH implementation, and in April 2012 post-ERH is shown in Appendix A, Tables A-3 and A-4. The data has been compared to MCLs shown in Table A-1. The findings are summarized in the chemistry box plots shown in Figure B-8. Numerous VOC’s were detected in the analysis; refer to the chemistry box plots presented. For the year 2007 (pre-ERH), tetrachloroethene (PCE), TCE, cis-dichloroethene (cis-1, 2, DCE), and vinyl chloride (VC) were also exceeding EPA limits. This is typically expected in a system with TCE contamination since TCE is a decomposed product of PCE, and TCE decomposes into cis-1, 2-DCE, VC and ethene. Toluene, benzene and chloroform were also detected in some wells. Limit exceedances for TCE were observed in the wells

within the domains of the site only. The monitoring wells located in the right of way of residential areas had traces of TCE but fell within the acceptable limits for EPA's MCLs and regional screening level (RSL) tap water standard. The highest concentrations of TCE were observed in a cluster of wells formed by DB-04, MW-24-110, MW-26-90, and DB-06 with values of 4,700 ug/L, 2,400 ug/L, 13,000 ug/L, and 70 ug/L, respectively, for the year 2007 pre-ERH. Table B-1 in Appendix B shows a summary of TCE concentrations pre-ERH, during ERH, and post-ERH treatment for each zone. Values above regulatory limits are highlighted red. This leads to the conclusion that TCE contamination is mostly of concern within Zone B and Zone C. Since contamination of the site is predominantly concentrated in Zone B and C, vapor intrusion is not an issue within the domain of Industrial Site 'P'. In order for vapor intrusion to occur, the contaminated groundwater must be superseded by a vadose zone that would enable the compounds to volatilize. Also, aside from the remediation technologies being implemented, the site is not operational.

The ERH system has been successful in decreasing the extent of the contaminant plume. In Appendix B, Figures B-9 through B-12 in show contamination plumes for TCE within the Perched Zone, Zone B, Zone C, and Zone D. Wells located in the impacted area like DB-04, MW-24-110, and DB-06 decreased from 4700 ug/L to 190 ug/L, 2400 ug/L to 200 ug/L, and from 70 ug/L to 5.9 ug/L, respectively. A decline in concentrations has been observed in most wells. However, there are a few for which the concentrations have slightly increased over time. This might be attributed to the migratory nature of the plume or a potential new source of contamination located off-site.

### **Residential Site 'L'**

This section presents an analysis of groundwater data collected from 31 monitoring wells at Industrial Site 'L'. The data includes groundwater elevations (Appendix A, Table A-6) from April 2012, and VOC concentrations collected during an April and October 2007 and 2012 field sampling events (Table A-7). The laboratory analytical results for samples extracted from monitoring wells present concentrations for series of VOCs.

#### **Groundwater Contours for 2012**

Groundwater elevations were measured at 31 locations throughout Industrial Site 'L'. The wells were screened at shallow, intermediate, and deep intervals with respect to the saturated zone. Data was initially analyzed by grouping wells based on the screening interval range. Contours were initially drawn for all three well types. The same pattern was present in the northern portion of the site (above the railroad tracks) in which rapid decline in groundwater elevations was observed closer to the river.

The groundwater elevations for the wells screened at shallow, intermediate, and deep intervals did not change significantly. For example, the groundwater elevation measurement for MW-003-WT screened at an interval of approximately 8 to 18 ft bgs at the water table was 739.60 ft bgs. The groundwater elevation measurement for MW-003-S screened at a shallow interval of approximately 10 to 20 ft bgs at the water table was 739.41 ft bgs. The elevation measurement for MW-003-I (interval 105-115 ft bgs) and

MW-003-D (1456 – 156 ft bgs) were 739.50 and 739.43 ft bgs. This implies that just one aquifer is present at the site.

Due to the small variations in groundwater elevations, only one contour map is needed to characterize groundwater flow at the site.



**Figure 4. Example of Adjacent Flush Mount Well Series in Industrial Site 'L'**

The shallow wells represent the most comprehensive package of data and were thus chosen to create the contours. Groundwater at the site flows in a northwestern direction near the southern portion of the site and gradually changes in a northeastern direction towards the river. A groundwater mound was noted at well MW-005-S with the highest elevation of 745.75 ft. It exhibits approximately a 5 ft difference when compared to the surrounding wells. Groundwater flows radially outwards from the mound. The groundwater contour is shown in Appendix C, Figure C-2.

### **Groundwater Sampling**

Groundwater samples were collected for the 31 wells listed in Table A-6. Samples were sent to a contract laboratory program (CLP) for analysis. Refer to Table A-7 for the analytical data showing the VOC concentration in  $\mu\text{g/L}$ . The results were compared to IDEM (30 year, sand soil) and EPA residential screening levels for groundwater in a vapor-intrusion scenario. Appendix C, Figures C-4 through C-6, summarizes the results. Compounds exceeding either maximum contaminant levels (MCL) or the vapor-intrusion screening criteria include bromodichloromethane, tetrachloroethene, trichloroethene, chloroethene, ethylbenzene, benzene, and vinyl chloride. TCE exceeded screening criteria in groundwater at thirteen locations for the October 2011 sampling and at twelve locations in the January 2012 sampling event. TCE concentrations seem to be higher in the northern area of the site, north of the railroad tracks. TCE was only detected in the wells screened at a shallow and intermediate interval. The contamination plume is not expected to have changed significantly from 2011 to 2012 since the TCE concentrations at sampling locations are about the same for the years 2011 and 2012.

### **Sub – Slab & Indoor Air Sampling**

Analytical Method TO-15 was used to collect sub-slab samples in accordance with the standard operating procedure (SOP) for sub-slab sampling. This is performed by drilling a hole in the foundation or slab. Stainless-steel fitting and tubing is installed and connected to a sub-slab vapor probe. The canister is set to extract the sample for approximately 24 hours (Figure 5).



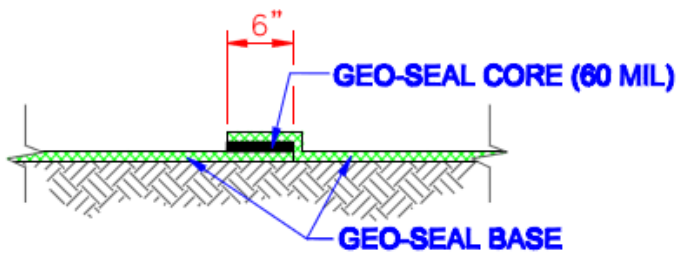
**Figure 5. Sub-Slab Sampling at a Residential Site**

Sub-slab samples were collected from 19 residences and indoor air samples were collected from 15. Appendix C, Table C-1 shows the results for the sub-slab samples (SS) and indoor air (IA) samples. Several VOCs exceeded EPA sub-slab screening values in all the sub-slab samples. These include tetrachloroethane, TCE, dibromomethane, dichloroethene, benzene, benzyl chloride, carbon tetrachloride, chloroform, cis 1,3, dichloropropane, methyl chloride, tetrachloroethene, and vinyl chloride. In 11 of the 19 sub-slab samples, VOC concentrations exceeded both IDEM's residential sub-slab action levels and EPA's subsurface vapor intrusion guidance. All residences had several VOCs present at concentrations above IDEM's residential indoor action levels. These include TCE, TCA, dibromomethane, dichloroethane, dichloropropane, chloroform and benzene. The sub-slab data confirms that vapor intrusion is an issue at Residential Site 'L'.

## 5. CONCLUSION

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It is recommended that vapor intrusion be addressed at Residential Site ‘L’ by retrofitting the existing homes with engineering controls. Engineering controls should be efficient in eliminating the entry routes, or by reversing the negative pressure or diffusion gradients driving the contaminants into the building. Active or passive mitigation systems may be implemented depending on the amount of vapor intrusion to be addressed. Active systems are preferred to produce a large decrease in vapor intrusion. Some active systems to be considered include drain-tile depressurization, block wall depressurization, and sub-membrane depressurization. Passive systems to be considered may include passive sub-slab venting, installing vapor barriers, and modifying the building’s foundation.



**Figure 6. Geo-Seal Barrier Coating**

One of the most common solutions consists of neutralizing or reversing the advective flow into the building by creating a positive pressure in the building or a negative pressure in sub-slab soil gas. According to EPA, this may be accomplished by installing a sub-slab ventilation system or sub-slab depressurization system. The system typically consists of a pipe

under the slab that uses a fan to extract soil gas from under the slab and vent it to the atmosphere (EPA, 2007). Another option is to eliminate the entry routes by sealing individual routes or applying a barrier membrane that blocks all entry routes from the soil gas; Geo-Seal is an example of this technology.

Continued monitoring for Industrial Site ‘P’ is recommended, specifically near the boundary bordering the residential area and north of the wells showing increased concentrations over time.

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## APPENDICES

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### APPENDIX A: DATA & RESULT TABLES

Table A-1: List of EPA MCLs and IDEM's Screening Values

Table A-2: Industrial Site 'P' Site Specific Remediation Levels

Table A-3: April 2012 Groundwater Monitoring Event Data for Industrial Site 'P'

Table A-4: Analytical Data of VOCs in Ground Water for Industrial Site 'P' (2007)

Table A-5: Analytical Data of VOCs in Ground Water for Industrial Site 'P' (2012)

Table A-6: October 2011 Groundwater Monitoring Event Data for Residential Site 'L'

Table A-7: Analytical Data of VOCs in Ground Water for Residential Site 'L' (2011 and 2012)

### APPENDIX B: INDUSTRIAL SITE 'P' MAPS

Figure B-1: Industrial Site 'P' General Map

Figure B-2: Perched Zone Groundwater Contour for Industrial Site 'P'

Figure B-3: Perched Zone Groundwater Contour for Industrial Site 'P' at Higher Resolution

Figure B-4: Zone A Groundwater Contour for Industrial Site 'P'

Figure B-5: Zone B Groundwater Contour for Industrial Site 'P'

Figure B-6: Zone C Groundwater Contour for Industrial Site 'P'

Figure B-7: Zone D Groundwater Contour for Industrial Site 'P'

Figure B-8: Volatile Organic Compounds Detected

Table B-1: TCE Concentrations Before, during and after the implementation of ERH

Figure B-9: TCE Contamination Plumes for the Perched Zone

Figure B-10: TCE Contamination Plumes Zone B

Figure B-11: TCE Contamination Plumes Zone C

Figure B-12: TCE Contamination Plumes Zone D

**APPENDIX C: RESIDENTIAL SITE 'L' MAPS**

Figure C-1: Residential Site 'L' Maps

Figure C-2: Residential Site 'L' Shallow Groundwater Contour

Figure C-3: Residential Site 'L' Deep Groundwater Contour

Figure C-4: Volatile Organic Compounds Detected in Shallow Zone (2011)

Figure C-5: Volatile Organic Compounds Detected in Shallow Zone (2012)

Figure C-6: Volatile Organic Compounds Detected in Deep Zone (2011 and 2012)

Table C-1: Sub-Slab and Indoor Air Sampling Results