

## **7.0 NATURE AND EXTENT OF CONTAMINATION**

The present understanding of the nature and extent of soil contamination beneath the VW&R facility and groundwater contamination in the WCP East Grand Avenue WQARF Site has been developed from data generated during previous investigations (HLA, 1994 and 1995; Fluor Daniel, 1997; and WESTON, 1998) and the current RI activities. The description of the VOC contaminants and their distribution in soil and groundwater are discussed in the following sections.

### **7.1 CONTAMINANTS OF CONCERN**

Several contaminants have been detected in soil and groundwater samples collected during previous and current investigations of the WCP East Grand Avenue WQARF Site. The primary contaminants of concern include PCE, TCE, and 1,1-DCE. These compounds have been detected in soil-gas and soil samples collected on the VW&R facility and in groundwater samples collected from wells in the WCP East Grand Avenue WQARF Site.

The State of Arizona has established relevant standards against which these contaminants are compared. Soil contaminant concentrations are compared to the Arizona Soil Remediation Levels (SRLs) and to the minimum GPLs. The SRLs are established in Arizona Administrative Code (AAC) R18-7-205 and consist of residential and non-residential standards. Contaminant concentrations in groundwater are compared with Aquifer Water Quality Standards (AWQS) for Arizona, which are established in AAC R18-11-406. The AWQSs include the EPA MCLs and are referenced in this document as AWQS/MCLs. The following table lists the relevant standards for the contaminants of concern at the WCP East Grand Avenue WQARF Site.

Contaminant of Concern	AWQS/MCL (µg/L) <sup>1</sup>	GPL (mg/kg) <sup>2</sup>	Residential SRL (mg/kg) <sup>2</sup>	Nonresidential SRL (mg/kg) <sup>2</sup>
PCE	5	1.3	53	170
TCE	5	0.61	27	70
1,1-DCE	7	0.81	0.36	0.8

<sup>1</sup>µg/L = micrograms per liter  
<sup>2</sup>mg/kg = milligrams per kilogram

The concentrations in groundwater of the three primary contaminants of concern have exceeded the AWQS/MCL in several locations. Maximum concentrations of PCE, TCE, and 1,1-DCE detected in groundwater samples collected from around the Site during the current RI sampling activities are 920 µg/L, 1,100 µg/L, and 210 µg/L, respectively. Historical concentrations of PCE and TCE detected in samples from monitor wells located on the VW&R facility have been as high as 1,800 µg/L and 2,700 µg/L, respectively.

## 7.2 OTHER DETECTED CONTAMINANTS

Other contaminants detected in groundwater during the WCP East Grand Avenue RI that exceeded the AWQS/MCLs include benzene, toluene, ethylbenzene, and xylenes (BTEX). Relevant standards for these contaminants are listed below.

Detected Contaminant	AWQS/MCL (µg/L) <sup>1</sup>	GPL (mg/kg) <sup>2</sup>	Residential SRL (mg/kg) <sup>2</sup>	Nonresidential SRL (mg/kg) <sup>2</sup>
Benzene	5	0.71	0.62	1.4
Ethylbenzene	700	120	1,500	2,700
Toluene	1,000	400	790	2,700
1,2-DCA	5	0.21	2.5	5.5
Carbon Tetrachloride	5	1.6	1.6	5.0

<sup>1</sup>µg/L = micrograms per liter  
<sup>2</sup>mg/kg = milligrams per kilogram

BTEX constituents were typically detected in wells located on or near documented LUST sites and were generally highest in ENT-MW-2, WCP-44, and WCP-202. Concentrations of these compounds in monitor wells located on the VW&R facility were either below the MDL or were

considered estimated values because the compound was detected above the MDL but below the laboratory reporting limit.

Although WCP-44 and WCP-202 are located near documented LUST sites, the high concentrations of benzene detected at these locations, up to 6,300 µg/L in WCP-202, appear to be the result of an unrelated benzene release. STL chemists evaluated the chromatograms and spectra for results from ENT-MW-2, WCP-44, and WCP-202. Results from ENT-MW-2 had a definite fuel hydrocarbon pattern and appeared to be attributable to a gasoline release (Wright and Kaczinski, 2002). Results for WCP-44, located southeast of ENT-MW-2, contained some hexane and pentane peaks but no large hydrocarbon peaks. The chemist determined that the results from WCP-44 appeared to have characteristics of both a possible fuel hydrocarbon release and a possible benzene release. Analytical results were also evaluated for WCP-202, located southwest of ENT-MW-2 and WCP-44. Based on a review of the chromatograms and spectra for this well, there were no hydrocarbon peaks present and the high benzene detections were attributed to a benzene release.

Concentrations of 1,2-DCA were detected above the AWQS/MCL in samples collected from MGL-1 and MGL-2 located on the Mogul facility. A bailed sample collected from ENT-MW-2 during Round 3 also had a 1,1-DCA concentration of 380 µg/L, which also exceeded the AWQS/MCL. There were no additional occurrences of 1,2-DCA in this well either before this sampling event or after this event, indicating this result was anomalous. This compound was also detected in samples collected from monitor wells located on the VW&R facility but at concentrations that did not exceed the AWQS/MCL. The exceedances of the AWQS/MCL observed in the Mogul wells appear to be localized in that area and therefore, 1,2-DCA is not being considered a contaminant of concern.

Carbon tetrachloride was detected in Hydropunch<sup>®</sup> groundwater samples collected from soil borings drilled on the VW&R facility during the vadose zone investigation. Concentrations of carbon tetrachloride met or exceeded the AWQS/MCL of 5 µg/L in Hydropunch<sup>®</sup> samples collected from SB-10, SB-16, and SB-17. Carbon tetrachloride was also detected in Hydropunch<sup>®</sup> groundwater samples collected during the installation of WCP-87 and WCP-93;

however, concentrations were below the AWQS/MCL. Concentrations of carbon tetrachloride in groundwater samples collected during groundwater monitoring events were also below the AWQS/MCL and therefore, carbon tetrachloride is not considered a contaminant of concern.

Concentrations of 1,1,1-TCA were observed in soil samples from earlier investigations of the facility (HLA, 1995). This compound was not identified in soil samples collected during this RI or in groundwater samples collected during the groundwater monitoring activities. Because it has not appeared in detectable concentrations during this investigation, 1,1,1-TCA is not considered a contaminant of concern and will not be discussed further.

### **7.3 CHARACTERISTICS OF THE CONTAMINANTS OF CONCERN**

The following sections describe the general characteristics of the three primary contaminants of concern. Table 7-1 lists the physico-chemical properties of PCE, TCE, and 1,1-DCE. Fate and transport mechanisms for these contaminants are discussed in Section 7.8 and the distributions of the contaminants are discussed in Sections 7.4 and 7.5.

#### **7.3.1 PCE**

PCE is a colorless liquid that has been historically used as a dry cleaning agent and as a chemical intermediate in the production of fluorocarbons. It is classified as a probable carcinogen to humans based on sufficient animal research evidence and limited human research evidence (Toxnet, 2001). It has moderate mobility in soil based on a soil adsorption constant ( $K_{oc}$ ) of approximately 303 milliliters per gram (mL/g) and may volatilize from dry soil surfaces (Fetter, 1994). With a specific gravity of 1.62, PCE is denser than water and as a free-phase liquid will sink when in contact with groundwater. It has a solubility in water of 150 mg/L (Cohen and Mercer, 1993).

#### **7.3.2 TCE**

TCE is a colorless liquid that has historically been used in degreasing operations as well as in the plastics, appliances, jewelry, automobile, textile, paper, glass and printing industries. TCE is also a byproduct of the anaerobic biodegradation of PCE. It is classified as a probable

carcinogen to humans based on sufficient animal research evidence and limited human research evidence (Toxnet, 2001). TCE has a moderate mobility in soils based upon an average  $K_{oc}$  of 152 mL/g and has the potential to volatilize from dry soil surfaces (Fetter, 1994). Sorption of TCE from the vapor phase onto soil is also possible. TCE is denser than water, with a specific gravity of 1.46. It has a solubility in water of 1,100 mg/L (Cohen and Mercer, 1993).

### **7.3.3 1,1-DCE**

1,1-DCE is a colorless liquid often used in the manufacturing of plastics, adhesives, and synthetic fibers. 1,1-DCE is also formed during the anaerobic biodegradation of TCE, by way of a minor pathway, and by the hydrolysis of 1,1,1-TCA (Toxnet, 2001). It is categorized as a possible human carcinogen, but a definitive classification cannot be established due to inadequate evidence from animal and human research (Toxnet, 2001). An estimated  $K_{oc}$  of 217 mL/g suggests that 1,1-DCE would have moderate mobility through soil (Fetter, 1994). 1,1-DCE is denser than water having a specific gravity of 1.21. The solubility of 1,1-DCE in water is 400 mg/L (Cohen and Mercer, 1993).

## **7.4 DISTRIBUTION AND TRENDS OF SOIL CONTAMINATION**

The results of the vadose zone investigation and previous investigations provide most of the available information concerning the distribution of contaminants in soils at the VW&R facility. Physical testing results of soil samples are presented in Appendix I and are tabulated in Table 7-2. Tables 7-3 through 7-5, presented by sampling event, summarize analytical results for VOCs detected in soil samples collected as part of this RI. All analytical results for current RI activities are presented in electronic format and are attached as Appendix G. Previous investigation results are presented in Section 1.3.

Analytical results from previous investigations and from Phase III samples of the RI confirmed the presence of TCE and PCE in subsurface soils in the areas of the VW&R facility where elevated VOC concentrations were detected in soil-gas samples collected in 1994. The detections of these compounds, however, did not exceed the minimum GPLs or the Arizona

SRLs established for TCE and PCE. Contaminant and lithologic cross sections of the soil borings drilled during the vadose zone investigation were prepared to evaluate the distribution of contaminants in soils on the VW&R facility (Figures 7-1 through 7-5).

The time elapsed since VOC products were documented to have been present on the site is approximately 31 years, suggesting that near-surface soils are unlikely to exhibit detectable concentrations of VOCs, even if surface releases occurred during the time that these chemicals were present on the facility. However, as discussed in Section 7.8.1, VOCs do not migrate readily through fine-grained materials and movement is impeded in moister soils; therefore, low concentrations of VOCs are more likely to be detected in near-surface fine-grained soils.

Soil-gas samples were collected at the VW&R facility in 1994 by HLA as described in Section 1.3.2. Elevated concentrations of PCE, TCE, and 1,1-DCE were located primarily in two areas (Figures 1-4, 1-5 and 1-6) (HLA, 1994). One area encompassed the former building foundation and extended southwest of it. The other area was located approximately 120 feet northwest of the former building foundation.

Near-surface soil contamination was detected in borings SB-11, SB-14, and SB-17. Results indicated the presence of PCE at 1 foot bgs with concentrations ranging from 0.062 to 0.093 mg/kg. TCE and PCE were also detected in a near-surface fine-grained unit at 21 feet bgs in borings SB-14 and SB-17 at concentrations ranging from 0.062 to 0.074 mg/kg and 0.069 to 0.072 mg/kg, respectively (Figures 7-3 and 7-4). PCE was detected in soil samples from SB-6 and WCP-15 at 20 to 21 feet bgs at concentrations of 0.0066 mg/kg and 0.065 mg/kg, respectively (Figures 1-7 and 1-8).

A zone of elevated PCE and TCE concentrations in the vadose zone occurred at the 56 to 71 feet bgs (elevation 1048 to 1087 feet amsl) depth interval beneath the facility. This zone is located at a lithological transition from coarse to fine-grained materials as illustrated in Figures 7-2 through 7-5. The transition from coarse to fine-grained material represents a location where lateral spreading would be expected to occur from reduction in vertical conductivity on a downward-migrating liquid. Soil samples collected from this zone contained concentrations of PCE ranging

from 0.044 to 0.220 mg/kg and TCE ranging from 0.060 to 0.250 mg/kg. The highest concentration of TCE was at approximately 61 feet bgs in SB-12 and SB-14. Soil samples collected at 61 feet bgs in SB-12 had the highest concentration of PCE at 0.220 mg/kg. Soil borings SB-12 and SB-14 are located approximately 75 feet northwest of the former VW&R building foundation. Soil samples collected from Phase VI well WCP-100 at this depth horizon contained PCE concentrations ranging from 0.077 mg/kg to 0.190 mg/kg and TCE concentrations from 0.087 mg/kg to 0.210 mg/kg.

Detectable concentrations of PCE and TCE were found in samples collected from several borings in the unsaturated zone above the water table. The depth-to-water at WCP-16 at the time of installation was approximately 106 feet bgs. Soil samples collected from the boring at 100 to 101.5 feet bgs indicated PCE and TCE concentrations of 0.088 mg/kg and 0.120 mg/kg, respectively. By 1999, when the Phase III vadose zone investigation was conducted, depth-to-water measurements under the facility varied from approximately 116 feet bgs to 121 feet bgs. Samples collected from SB-8, SB-10, SB-12, SB-16, and SB-17 contained PCE concentrations ranging from 0.081 mg/kg to 0.340 mg/kg and TCE concentrations ranging from 0.058 mg/kg to 0.480 mg/kg at approximately 120 feet bgs (Figures 7-2 and 7-4). Soil samples collected from the borings of the Phase VI wells, WCP-100 and WCP-200, also had detectable concentrations of PCE and TCE at 116 feet to 126 feet bgs. Concentrations of PCE in the unsaturated zone above the water table from WCP-100 ranged from 0.170 mg/kg to 0.190 mg/kg and TCE was detected at 116 and 121 feet bgs at a concentration of 0.160 mg/kg. Samples collected from WCP-200 at depths from 116 feet bgs to 126 feet bgs indicated PCE at a concentration of 0.390 mg/kg to 0.550 mg/kg and TCE at a concentration of 0.270 mg/kg to 0.410 mg/kg. Concentrations of 1,1-DCE were also detected in WCP-200 in samples from depths ranging from 116 feet bgs to 126 feet bgs at concentrations ranging from 0.057 mg/kg to 0.140 mg/kg (Figure 7-5). As stated previously, the unsaturated zone above the water table is also located at a lithologic transition from coarse to fine-grained materials.

#### **7.4.1 Saturated Soil Samples**

Soil samples were also recovered from the saturated zone and analyzed for VOC concentrations, as identified in Tables 7-3 through 7-5. Many of these samples were collected at the same approximate depth as Hydropunch<sup>®</sup> samples to provide data from which to compare concentrations in groundwater samples with those in the aquifer materials that contain them. These samples should not, however, be considered “soil sample” nor should they be compared with the SRLs and/or GPLs for vadose zone soils.

### **7.5 DISTRIBUTION AND TRENDS OF GROUNDWATER CONTAMINATION**

Evaluation of groundwater contaminant distribution was based on analytical results obtained from samples collected during each round of groundwater monitoring and from Hydropunch<sup>®</sup> samples collected during the vadose zone investigation. Hydropunch<sup>®</sup> contaminant distribution is discussed in Section 7.5.1 and the lateral distribution of contaminants based on groundwater monitoring data is discussed in Section 7.5.2. The vertical extent of groundwater contamination is discussed in Section 7.5.3.

Groundwater elevations have shown a general decline since the first groundwater monitor well was installed on the VW&R facility in 1997 (Figures 2-21 through 2-24). WESTON compared 1,1-DCE, PCE, and TCE concentrations and groundwater elevations over time in seven monitoring wells where concentrations were consistently above the AWQS/MCL. The monitor wells evaluated included WCP-15, WCP-16, WCP-17, WCP-28, WCP-30, WCP-45, and WCP-87 (Figures 7-6 through 7-12).

Groundwater levels declined approximately 17 feet in WCP-15, WCP-16, and WCP-17 since 1997, approximately 14 feet in WCP-28 and WCP-30 since 1998, approximately 6.5 feet in WCP-45 since 1999, and approximately 4 feet in WCP-87 since 2001. Contaminant concentrations obtained from groundwater samples collected from these wells have also shown a general decrease over time. The groundwater-vadose zone interface is typically located in a zone of fine-grained sediments. These fine-grained sediments have a tendency to retain contaminant-

rich pore water through capillary forces during declines in the water table, which appears to result in a reduction of VOC concentrations in the groundwater.

### **7.5.1 Hydropunch® Samples**

Hydropunch® samples collected from 10 boreholes drilled on the VW&R facility (as described in Section 4.2.1) and from selected monitor well boreholes drilled during Phases III through VI of the WCP East Grand Avenue WQARF Site RI were described in Section 4.0. A summary of detected concentrations of VOCs in Hydropunch® samples is presented in Tables 7-6 through 7-9. All analytical results are presented in electronic format and are attached as Appendix G.

WESTON evaluated the Hydropunch® sample results from the boreholes drilled during the Phase III vadose zone investigation. Concentration contours were developed to evaluate the lateral distribution of the contaminants of concern beneath the VW&R facility (Figures 7-13 through 7-15). These concentration contour results generally correspond to earlier soil-gas results from the HLA soil-gas survey conducted in 1994 and to soil sample results from the corresponding wells. As illustrated on the figures, the highest concentrations of PCE and 1,1-DCE were found in samples collected from boring SB-10, located southwest of the former building foundation. The highest concentration of TCE was from SB-8, located underneath the former building foundation.

The results for Hydropunch® samples collected prior to well installations are presented on Figure 7-16. Generally, the Hydropunch® sample results mirror the distribution of the contaminant plume as defined by the groundwater monitoring data. An exception to this correlation occurs for the first groundwater sample collected after the Hydropunch® sample collection. Hydropunch® sample results tended to be greater than the groundwater monitor well result in samples collected closer to the VW&R facility. Sample locations at the perimeter of the plume area typically had Hydropunch® sample results with lower concentrations than the groundwater monitor well sample.

The concentration differences can be generally attributed to two factors. First, samples collected using the Hydropunch<sup>®</sup> method were generally collected close to the groundwater-unsaturated zone interface. During groundwater monitoring, the pump intake was typically set 5 to 10 feet below the groundwater interface. Groundwater contaminant concentrations tend to decrease with depth near the source area, where contaminants have adsorbed to fine-grained materials at the groundwater-unsaturated zone interface as groundwater elevations have decreased. Therefore, samples collected closer to the source and to the groundwater-unsaturated zone interface are expected to yield greater contaminant concentrations than samples collected 5 to 10 feet below this zone. As contaminated groundwater moves away from the source area, the effects of diffusion and dispersion tend to reduce this concentration stratification.

The second contributing factor in the concentration variances between Hydropunch<sup>®</sup> samples and groundwater monitoring well samples is the monitor well purging process. As the monitor wells are purged, water with either lower or higher concentrations of contaminants can be mixed with groundwater at the well location. Additional discussion of the effects of purging methods on sample results can be found in Section 7.5.2.2.

## **7.5.2 Groundwater Monitoring Data**

Groundwater monitoring activities associated with this RI began in December 1999 and were conducted monthly for the first three rounds of sampling. During those sampling events, groundwater samples were collected using both a disposable bailer and directly from the pump, as discussed in Section 5.0. Samples were collected using both methods in order to compare sample results.

Detected concentrations of VOCs are presented in Tables 7-10 through 7-24. All groundwater monitoring analytical results are presented in electronic format and are attached as Appendix G. Table 7-25 presents field data collected during each round of groundwater sampling. Analytical data for PCE, TCE, and 1,1-DCE were used to develop concentration contour maps for most of the groundwater sampling rounds. Concentration contour maps were not developed for Round 12 because this sampling event tested the use of PDB sample collection methods and a limited

number of monitor wells were sampled. An evaluation of PDB sample data is presented in Section 7.5.2.3. Concentration contour maps were also not developed for Round 14 due to the incomplete data set resulting from the sampling problems discussed in Section in 4.2.4.2.

Figures 7-17 through 7-52 present PCE, TCE, and 1,1-DCE concentration contour maps for groundwater samples collected using the pump discharge sample collection method for Rounds 2 through 15, excluding Rounds 12 and 14. To maintain comparability of data, the following discussion is limited to the distribution of groundwater contamination based on the results of the pump discharge samples only. A discussion of the effects of the bailer sample collection method on sample results and distribution of contamination is presented in Section 7.5.2.1.

The orientation of the long axis of the 1,1-DCE, PCE, and TCE concentration plumes for Rounds 2 through 6 vary from those of subsequent rounds. The plume appears to trend in a more west-southwesterly direction in the early rounds compared with a southwesterly direction beginning with sampling Round 7, conducted in February and March 2001. This apparent change in plume direction is a function of the distribution of wells available for sampling during the initial rounds, rather than any change in actual contaminant distribution. Round 7 groundwater sampling followed the installation of nine additional monitor wells. The additional monitor well data and the monitor well distribution provided a more clear definition of contaminant distribution and plume orientation. The SRP well, 10.5E-7.5N, has not been pumped since May 1999 and therefore, had no effect on plume orientation.

Based on the concentration contours, the lateral distribution of groundwater contamination varies slightly by contaminant, but the center of the plume is generally located around WCP-16 and WCP-30. The center of the plume is more clearly defined in Round 7 with the addition of WCP-87, and extends southwest from the center of the VW&R facility. WCP-93 was installed on the southeast corner of the facility and sampled during July 2001 as Round 11. This well provides additional definition of the plume southeast of the VW&R facility.

Concentrations of PCE, and to a lesser extent TCE, in samples from WCP-28 collected in Rounds 2 (Figures 7-17 and 7-29) and 4 (Figures 7-18 and 7-31) appear to be anomalously high

when compared to the entire data set. Minor local variations in groundwater flow may have contributed to the anomalous readings. The PCE result was flagged as possibly having a high bias due to unacceptable surrogate recoveries in Round 2, contributing to the high reading for this compound. Subsequent sampling demonstrates that these high readings are not representative of the typical concentration of VOCs in groundwater at this location.

The reasons for the increased VOC concentrations in WCP-16 and decreased VOC concentrations in WCP-87 during Rounds 11 through 13 are likely related to a combination of two factors: the overall groundwater elevation decline in the area and a change in monitor well purge methods. Samples for each of these sampling rounds were collected using the pump discharge method; however, the purge method varied. Samples from WCP-87 were collected following low-flow purge methods in Rounds 7, 8, 9, and 11. Three well-casing volumes were removed prior to sample collection during Rounds 10, 13, and 15.

The only deep well drilled during the investigation, WCP-48, is located west of the VW&R facility. Results of the deep well samples collected from WCP-48 are not posted on the contour maps because it is completed in a different hydrogeologic zone than other wells in the WCP East Grand Avenue WQARF Site monitoring network. The pump depth was consistently set at approximately 235 feet bgs during sampling of this well. Analytical results indicate that only 1,1-DCE is present at that depth. The concentrations of 1,1-DCE ranged from 0.6 µg/L to 0.8 µg/L. The AWQS/MCL for 1,1-DCE is 7 µg/L.

#### **7.5.2.1 Comparison of Bailer and Pump Discharge Sample Collection Methods**

Groundwater concentration contours for PCE, TCE, and 1,1-DCE in samples collected using the bailer method during the first three groundwater sampling events are presented in Figures 7-53 through 7-61. Consistent with sample results using the pump discharge sample collection method, groundwater analytical results obtained during the first three sampling events using the bailer sample collection method indicated that concentrations of PCE, TCE, and 1,1-DCE were typically highest in the samples from monitor wells near or on the VW&R facility. These wells, WCP-15, WCP-16, WCP-17, WCP-28, and WCP-30, also had the greatest variability in

contaminant concentration results when comparing the bailer sample collection and pump discharge sample collection methods. At greater distances from the VW&R facility, contaminant concentrations were similar for samples collected with the bailer and those collected directly from the pump discharge.

In general, samples collected using the bailer sample collection method had higher VOC concentrations than comparative samples collected using the pump discharge method. As discussed previously, VOC contaminants are retained in the soils near the groundwater interface because of the decline in groundwater elevation. The variation in contaminant concentrations between the bailer and pump discharge sampling methods appears to be related to the retention of VOCs in the soils. When using the bailer collection method, the groundwater sample is collected closer to the groundwater-vadose zone interface than the pump discharge sample, resulting in higher groundwater sample concentrations. When moving toward the outer limits of the contaminant plume, concentrations of contaminants retained in capillary fringe soils are lower, resulting in less variation between the sampling methods.

When comparing the two sampling methods, the apparent center of the plume also differs. As shown in Figures 7-53 through 7-61, the center of the plume for the bailed samples is located east of the center of the plume for the pump discharge samples and is predominantly positioned below the VW&R facility. The highest concentration contour line, as defined by the bailed sample results, most likely also defines the lateral extent of contamination retained in the fine-grained soil material at the groundwater-vadose zone interface.

#### **7.5.2.2 Comparison of Purging Methods**

During Rounds 9 and 10, groundwater samples were collected following two different purge methods as described in the project FSP and in Section 5.3 of this report. The sampling events were conducted approximately within two weeks of each other to minimize the effects of time and declining groundwater elevations on sample results and to obtain a more valid comparison of results based on purge method differences alone.

Evaluation of the June 2001 low-flow purge round (Round 9) and the June 2001 three-casing volume purge indicated that the sample results from Round 10, in which the three-well purge method was used, are generally lower than Round 9, where the low-flow purge method was used. The differences in concentrations illustrated by the PCE contour maps were most significant closer to the center of the contaminant plume, particularly in monitor well WCP-16 on the VW&R facility and WCP-30 just west of the VW&R facility (Figures 7-24 and 7-25). Concentrations obtained from samples collected from the same well using each of the two methods were compared by calculating the relative percent difference (RPD). RPDs for WCP-16 and WCPO-30 are presented in the following table.

WCP-16	Concentration (µg/L)		RPD
	Round 9	Round 10	
1,1-DCE	43	17	87%
PCE	130	44	99%
TCE	210	55	117%
<b>WCP-30</b>			
1,1-DCE	72	27	91%
PCE	230	91	87%
TCE	150	42	113%

The greater differences between the two purging methods at sampling locations closer to the source area can be explained by the following reasons. The three-casing volume purge method results in the removal of greater volumes of groundwater, which results in a greater potential for dilution as groundwater outside the contaminated zone is drawn into the sampling zone (Vroblesky, 2001). Additionally, the three-casing volume purge method increases the potential for groundwater aeration and the likelihood of stripping VOCs from the water. In areas of higher concentration, volatilization of the contaminants is greater.

### 7.5.2.3 Evaluation of Passive Diffusion Bag Samplers

Samples were collected with PDB samplers in nine monitor wells as described in Section 5.3.2. Groundwater samples were also collected using the pump discharge and low-flow purge method concurrently with the PDB samplers for comparison. Table 7-26 shows the analytical results for each sampling method and the sample collection depth. Analytical results are also presented on

Figures 7-62 through 7-64. The overall objective of the investigation was to test the feasibility of using PDB samplers for future studies and monitoring in the WCP East Grand Avenue WQARF Site. The following is a general discussion of PDB samplers compared to traditional purge and sample methods.

The feasibility of using PDB samplers is mainly dependent on the objectives of the project (Vroblesky, 2001). PDB sampling may be appropriate if the goal of the investigation is to monitor higher concentrations or to evaluate stratification of contaminants within the well screen. In areas where vertical stratification is anticipated, using multiple PDB samplers may more fully characterize the contaminated horizon than using a single PDB sampler. The use of PDB samplers eliminates the need for purging the well; therefore, the area of the screened interval that contributes water to the sample is not as great as that for a purged sample, and the potential for mixing stratified layers and dilution of the sample is reduced.

Samples collected using traditional purge-and-sample methods may be more appropriate if the objective of the investigation is to determine the average concentrations for the entire screened area. As discussed previously, pumping results in a mixing of vertical layers within the screen interval and potentially mixes water from outside the contaminant plume with contaminated water, depending on the flow rate at which water is pumped and on the quantity of water pumped.

PDB sample results compared to purge-and-sample results will generally be greater due to the above reasons. Although low-flow purging methods still can integrate water within the radius of pumping influence, samples collected using low-flow purge methods will typically be more similar to samples collected with PDB samplers than multiple casing volume purge samples (Vroblesky, 2001).

As expected, based on the above discussion, the contaminant concentrations in PDB samples collected during Round 12 were greater than concentrations from samples collected using the pump discharge method. It is unclear how much of the variance in sample concentration between the two sample collection methods is a result of the method and how much is a result of

chemical stratification because the pump sample was not collected at the same depth as a PDB sample. Although a difference in sample concentration was expected, chemical stratification in the screen interval was indicated based on results from each of the wells where two PDB samplers were installed.

PDB sample results from WCP-16, WCP-17, WCP-28, and WCP-29 indicate that the highest concentrations of contaminants are close to the groundwater-vadose zone interface and decrease with depth. The contaminant concentrations increase with depth as you move farther from the center of the VW&R facility.

The lithologic logs for WCP-87 indicate coarse-grained sediments are dominant from approximately 117 feet bgs to approximately 138 feet bgs. A narrow band of fine-grained sediments is present from 130 feet bgs to 133 feet bgs. Fine-grained sediments become dominant from approximately 138 feet bgs to 153 feet bgs. Based on the lithology, groundwater contaminants would be expected to migrate more readily both horizontally and vertically through the coarse-grained sediment with migration becoming more retarded as the contaminants enter the finer-grained materials. The PDB sample concentrations for WCP-87 are lower in the sample collected at approximately 124 feet bgs when compared with the sample collected at approximately 149 feet bgs.

PDB sample results from WCP-93 also increase with depth, although the reasons are less clear based on the lithology. Lithologic logs prepared for WCP-93, located on the southeast corner of the VW&R facility, indicate fine-grained materials are present from approximately 93 feet bgs to 147 feet bgs. WCP-93 is located closer to the source areas, and therefore additional lateral migration throughout the fine-grained zones may be occurring in the WCP-93 vicinity.

### **7.5.3 Vertical Extent of Groundwater Contamination**

The overall vertical extent of groundwater contamination was evaluated using the Hydropunch<sup>®</sup> data and groundwater monitoring data collected from WCP-48. In 1999, Hydropunch<sup>®</sup> samples were collected from borings SB-16 and SB-17 at approximately 122 feet bgs, 142 feet bgs, and 182 feet bgs. Concentrations of VOCs in these samples were greatest at the groundwater

interface at 122 feet bgs and decreased with depth. VOCs were not detected above the MDL at 182 feet bgs. Analytical results from Hydropunch<sup>®</sup> samples collected prior to the installation of wells WCP-87, WCP-100, and WCP-200 in 2001 indicated VOCs were present at concentrations significantly above AWQS/MCLs at 153 feet bgs.

Data collected from the deep monitor well, WCP-48, which is downgradient from the above mentioned Hydropunch<sup>®</sup> samples, indicate that only 1,1-DCE is present in groundwater at sample depths of 235 feet bgs. As stated previously, concentrations of 1,1-DCE in WCP-48 are well below the AWQS/MCL.

Based on these data, the vertical extent of groundwater contamination appears to be within the range of 153 feet bgs and 235 feet bgs. Further definitive characterization of the vertical extent of groundwater contamination will be addressed during the FS, if needed, based on the selected remedial alternative.

## **7.6 CONTAMINANT SOURCES**

### **7.6.1 VW&R Facility**

Historical records and information obtained from VW&R indicated various chemicals were stored and distributed at the facility, including acids, bases, solvents, chlorinated solvents, pesticides, and herbicides. TCE use at the facility has been confirmed and PCE is believed to have been one of five unidentified repack products (Section 1.2.1).

The distribution of contaminant concentrations in soil-gas, soil, and groundwater during this investigation and previous investigations indicates a primary source area of the contaminants of concern near and under the former building foundation. Although not a contaminant of concern, the distribution of carbon tetrachloride in groundwater also appears to be confined to wells located on the VW&R facility.

Information obtained from VW&R indicated that areas to the west and east of the former building foundation were used for bulk product repackaging. The rinsate generated during the cleaning of the transfer hoses used in the repackaging process was routinely poured on the

asphalt in the repackaging areas and incidental spills were known to have occurred in these areas. The occasional disposal of unsalable product to the ground surface north of the former building foundation has also been reported (Vopak, 2000). Stained soil has been observed in historical aerial photographs of the facility.

## **7.6.2 Additional Contaminant Sources**

An additional potential TCE source upgradient from the VW&R facility is indicated by groundwater contaminant contours. Data are insufficient to evaluate the possibility that upgradient occurrences of TCE in groundwater near WCP-41 are caused by an additional potential source or from transport mechanisms.

### **7.6.2.1 Mogul Facility**

WESTON completed a review of ADEQ's files on previous investigations at the former Mogul Property, located approximately 1,900 feet south-southwest of the VW&R facility (Figure 2-25). Results of this review are outlined in Section 2.9.5. Three monitor wells installed as part of a previous investigation conducted at Mogul were added to the VW&R groundwater-sampling network during Round 8. VOC concentrations detected in groundwater samples collected from the Mogul wells since sampling for the VW&R RI began include PCE, TCE, 1,2-DCA, and 1,1-DCE. Benzene has also been detected. Of the contaminants that have been detected in the Mogul wells, TCE appears to be the most significant, ranging in concentration from 4 µg/L to 9 µg/L (Figures 7-35 through 7-39). The contaminants in this plume appear to be from an additional source located at or near the Mogul facility and are not attributable to releases from the VW&R facility. Additionally, concentrations of VOCs detected in WCP-92, installed southeast of the Mogul facility, can be attributed to the contaminant source at Mogul.

### **7.6.2.2 Benzene Contamination**

WESTON evaluated other facilities that may have contributed to groundwater contamination within the WCP East Grand Avenue WQARF Site, including several facilities that had a release from a UST. Details of this evaluation are presented in Section 2.9.

Chromatograms and spectra from groundwater samples collected from three monitor wells, ENT-MW-2, WCP-44, and WCP-202, were evaluated to determine if high benzene concentrations could be attributed to documented fuel hydrocarbon releases known to be present at the former Fedmart facility.

Based on chromatogram and spectra evaluations (Section 7.2), high benzene concentrations in WCP-202 (5,900 µg/L to 6,300 µg/L) appeared to be the result of a pure benzene release. The closest downgradient monitor well to WCP-202 is WCP-96, which is approximately 675 feet southwest. Concentrations of benzene in samples from that well have been below the detection limit. The source of the benzene release is unknown at this time.

Results from WCP-44 appeared to be influenced by both fuel hydrocarbon releases and a benzene release (Wright and Kaczinski, 2002). Gasoline contamination in WCP-44 and in ENT-MW-2 is most likely attributable to releases from the former Fedmart/Sunbelt property. The unknown benzene source that is affecting WCP-202 may also be contributing to benzene concentrations in WCP-44. Benzene concentrations in WCP-44 were detected at a maximum concentration of 2,800 µg/L.

## **7.7 POTENTIAL FOR NATURAL BIODEGRADATION**

The most important process for the natural biodegradation of PCE, TCE, and 1,1-DCE is reductive dechlorination under anaerobic conditions (EPA, 1998). All three compounds are resistant to aerobic degradation; however, TCE may be degraded cometabolically (Toxnet, 2001).

In general, reductive dechlorination occurs by the sequential loss of chlorine atoms. PCE will degrade to TCE, to DCE, to vinyl chloride, and then to ethene. The rate of reductive dechlorination varies for each of the compounds. PCE is the most oxidized and therefore, is most susceptible to reductive dechlorination. Vinyl chloride is the least susceptible to reductive dechlorination because it is the least oxidized (EPA, 1998). Reductive dechlorination has been demonstrated under nitrate-and iron-reducing conditions but the most rapid biodegradation rates occur under sulfate-reducing and methanogenic conditions (EPA, 1998). In order for reductive

dechlorination to occur, there must be a sufficient source of carbon for microbial growth. Potential carbon sources include natural organic matter and fuel hydrocarbons.

Sufficient data have not been collected to determine the exact potential for natural biodegradation at the WCP East Grand Avenue WQARF Site. Based on DO and redox data collected in the field during groundwater sample collection (Table 7-24), the conditions within the screened portion of the aquifer appear to be generally aerobic, which is not conducive to reductive dechlorination, with the exception of the leading edge of the plume. Analytical results of groundwater samples are also not indicative of natural biodegradation. Concentrations of vinyl chloride above the MDL have not been indicated in any groundwater sample collected to date. Additionally, the presence of *cis*-1,2-DCE, the most prevalent of the DCE isomer daughter products, has been indicated at low concentrations in only a few monitor well locations. This isomer could also have been present as part of a mixture in a solvent packaged at the facility; therefore, its presence is not a clear indication of natural biodegradation.

As stated above, anaerobic conditions are indicated near the leading edge of the plume, specifically near ENT-MW-2, WCP-44, WCP-88, and WCP-202. These wells also correspond with elevated BTEX concentrations detected in groundwater samples. Due to the anaerobic conditions and the presence of a potential carbon source (BTEX constituents), this area would have a greater potential for natural biodegradation. However, additional data are needed to further evaluate the potential for natural biodegradation. Data regarding specific natural biodegradation indicator parameters have not been collected to date. Future analyses of the following parameters are needed to more completely evaluate the conditions in the area.

- Nitrate
- Sulfate
- Sulfide
- Iron (II)
- Methane, ethane, and ethene
- Chloride
- Dissolved organic carbon
- Alkalinity

## **7.8 FATE AND TRANSPORT**

The environmental fate and transport of a contaminant is controlled by the compound's physico-chemical properties and by the nature of the subsurface medium, as well as the geochemical conditions of the material through which the contaminant is migrating.

Each phase of the RI was designed to provide additional information to assess fate and transport of the identified contaminants of concern. This information included the definition of lateral and vertical extents of groundwater contamination in the WCP East Grand Avenue WQARF Site, aquifer properties, and physical characteristics of the aquifer materials. Aquifer properties and characteristics were discussed in Section 2.0. General fate and transport processes of and their application to site-specific conditions are discussed below.

### **7.8.1 Transport in Soils**

Based on the specific gravity and  $K_{oc}$  values for PCE, TCE, and 1,1-DCE, these VOC liquids will pass more quickly than water through an unsaturated soil horizon, leaving less residual liquid in the soil and dissipating more rapidly from the soil. TCE and 1,1-DCE are expected to have high mobility in soil, while PCE is expected to have moderate mobility in soil (Table 7-1)

The size and interconnectedness of the pore space in the soil, measured by permeability, also affects retention of liquids in soil. Small pore spaces retain water by capillary forces. Coarse gravels and cobbles do not retain liquids passing through them because of their large, interconnected pore spaces. Extremely fine particles, such as silt and clay, retain liquids by the capillary forces produced by their small pore sizes and reduced interconnectedness of the pores. Thus, VOC contamination would be expected to dissipate (i.e., drain and volatilize) most rapidly in coarse-grained soils, such as gravel and sand, and least rapidly in silts and clays.

Volatilization of TCE, PCE, and 1,1-DCE from moist soil surfaces is an important fate process given their Henry's Law constants (Table 7-1). The moisture content of a soil is a significant factor in migration and retention of VOCs both in liquid and vapor phases. Moisture filling the pores of a soil can act as a barrier to migration of VOC liquids. Conversely, penetration of VOC

liquids through the vadose zone is enhanced by dry soil conditions (Cohen and Mercer, 1993). Moist soils inhibit downward migration and can result in lateral migration of VOC liquids.

Contact of VOCs in liquid or vapor phases with moisture in soils results in VOC contamination of the soil moisture, which is also known as pore water. Release of VOCs dissolved in pore water is typically much slower than volatilization from a free-phase VOC liquid. Therefore, moist soils retain evidence of VOCs that have passed through the soil column longer than equivalent soils with low moisture content (Cohen and Mercer, 1993).

Applying these VOC soil migration principles to the site-specific conditions at the former VW&R facility provides the framework for analysis of the soil site data. Boring logs for monitor wells WCP-15 and WCP-16 describe the soil beneath the facility as being dry to moist (Appendix A). Actual moisture content of soil samples was not analyzed until the Vadose Zone Investigation and during later well installations (Table 7-27). Most of the soil samples recovered from borings at the facility were characterized as being dry (less than 10 percent) to moist (greater than 18 percent), thereby enhancing the speed of vertical migration in the soils and limiting the amount of residual contamination in the dry soils.

Soils beneath the facility vary from sands and gravels to silts and clays (Figures 7-2 through 7-5). Transitions from coarse sediments to fine sediments result in reduced permeability, which may cause ponding and lateral migration of VOCs. VOC migration in the coarse sediments is likely to be nearly vertical, presenting a relatively small target for a vertical soil drilling and sampling program. Coarse sediments with low moisture content are unlikely to have residual VOC contamination even in areas where VOC liquids may have passed through from a potential surface release.

Most of the soil samples with detectable concentrations of TCE and PCE recovered from beneath the VW&R facility were from fine-grained sediments consisting of silts and clays (Figures 7-1 through 7-5). Several of the samples with TCE and PCE contamination were recovered from the top of a fine-grained unit, immediately beneath coarser, sand-dominated units. The observed detections of contaminants at the top of fine-grained units is consistent with downward migration

of VOCs that would tend to spread laterally at the transition from coarse sediments to fine sediments due to reduction in permeability.

### **7.8.2 Transport in Groundwater**

VOCs in groundwater are transported in the direction of groundwater flow through advection and in all directions through the processes of diffusion and dispersion. Advection is movement parallel to groundwater flow paths either under the influence of gravity (unconfined conditions) or pressure (confined conditions). However, contaminants can disperse perpendicular to groundwater flow lines, dependent on the concentration of the contaminant, the quantity of the contaminant released, the hydraulic gradient and the tortuosity of the groundwater flow system. In groundwater, chemicals gradually spread and occupy an increasing aquifer volume beyond what would be expected from advective transport solely due to groundwater movement. The spreading of a chemical mass is called dispersion. Dispersion has both advective and diffusive components. Diffusion is the process of contaminant movement from areas of high concentration to areas of lower concentration by random molecular action. Diffusion takes place in all directions from a source of high concentration. Rates of diffusion, however, are typically much lower than rates of advective (flow) transport and therefore are typically a minor component of dispersion of contaminants in groundwater systems. Dispersion is affected by local groundwater velocity, in both direction and magnitude, and by how tortuous the flow paths are. Flow velocity variations occur as a result of changes in porosity, variations in hydraulic conductivity, and the presence of retarding layers. Dispersion takes place both longitudinally (in the direction of groundwater flow) and transversely (perpendicular to groundwater flow). Longitudinal dispersion is greater than transverse dispersion. Thus, a VOC dispersion plume is typically elongated in the direction of flow, emanating from the source area.

The general direction of contaminant migration across the site is consistent with the groundwater flow pattern. The groundwater contaminant plume appears to extend to the southwest from beneath the VW&R facility (Figures 7-28, 7-40, and 7-52), following the southwesterly groundwater flow typical of the WCP East Grand Avenue WQARF Site (Figure 2-20). The

downgradient extent of PCE and 1,1-DCE concentrations appears to be defined by recent samples from WCP-88. TCE, however, is present in recent samples from WCP-88 and from WCP-94 at concentrations well above the AWQS/MCLs (Figure 7-40). WCP-94 appears to be on the flow path of the known contaminant plume. It is unclear whether these TCE concentrations are related to the main body of the WCP East Grand Avenue WQARF Site plume or are associated with an undefined source.

Because PCE, TCE, and 1,1-DCE are denser than water, vertical migration in the saturated zone may occur. The extent of the vertical migration of the contaminant plume is dependent upon the aquifer materials and the presence of a free-phase VOC liquid in the saturated zone. As in soil migration, VOC movement would be greater in coarse-grained areas and more retarded in finer-grained aquifer materials. Based on analytical results from soil borings and groundwater monitoring activities at the WCP East Grand Avenue WQARF Site, there has been no indication of the existence of free-phase VOCs beneath the site.

Dissolved PCE, TCE, and 1,1-DCE migrate readily with groundwater, but their movement is retarded by adsorptive and absorptive processes. The  $K_{oc}$  values for TCE and 1,1-DCE indicate that these VOCs are not expected to adsorb to suspended solids and sediment in the groundwater. However, adsorption of TCE and 1,1-DCE onto suspended solids or sediment in groundwater depends upon the fraction of organic carbon ( $f_{oc}$ ) of the sediments in the aquifer. For aquifer materials low in organic carbon, direct sorption onto mineral phases of the soil can become important. The adsorption of a contaminant onto an aquifer material results in a reduction of concentration in the aqueous phase and a “retardation” of the velocity of contaminant migration. Retardation of TCE and 1,1-DCE occurs because these chemicals are nonpolar and this causes them to partition to the organic matter in the soil. Partitioning is a reversible process; molecules that have partitioned to the organic matter will move back into the groundwater as relative concentrations change. Retardation and, therefore, retardation factors are a function of the  $f_{oc}$  of the aquifer.

In order to determine the  $f_{oc}$  of the soil at any given site, an analysis for Total Organic Carbon (TOC) must be conducted on the soil. TOC analysis was done on selected soil samples collected

during the WCP East Grand Avenue WQARF Site RI. Results indicate that TOC is less than 0.12 percent (Table 7-2). Based on these results, retardation due to organic content of the aquifer material is expected to be negligible.

Saturated soils, especially at the top of the groundwater zone, can form a barrier to migration resulting in ponding or lateral migration of free-phase VOC liquids in addition to direct groundwater contamination. The lateral migration of VOCs in soils at the groundwater interface, or capillary fringe area, contributes to the lateral migration of contaminated groundwater. As groundwater levels decline, VOCs may be retained in the soils or sorbed to soil particles at the capillary fringe, thereby decreasing the contaminant concentrations in the groundwater. The contaminated capillary fringe area can act as an episodic source for groundwater contamination, particularly if groundwater elevations fluctuate periodically.

### 7.8.3 Groundwater Transport Calculations

The transport of VOCs in groundwater is first dependent upon the properties of the soil matrix supporting the advective and diffusional flow system. Other considerations include physico-chemical interactions between the VOCs and the soil matrix. The affinity of a VOC for soil is defined by the solid-water partition coefficient (also known as the distribution coefficient),  $K_d$ . The distribution coefficient relates to the mass of contaminant dissolved in groundwater to the mass sorbed to the soil and is calculated using the following equation:

$$K_d = K_{oc} f_{oc}$$

where:  $K_d$  = Distribution coefficient, in milliliters per grams soil ( $\text{mL}_{\text{water}}/\text{g}_{\text{soil}}$ )  
 $K_{oc}$  = Organic Carbon Partition Coefficient, in milliliters water per grams organic carbon  
 $f_{oc}$  = Fraction of organic carbon, in grams organic carbon per grams soil

The retardation factor of a VOC in the soil present at a site can be calculated using the following equation:

$$R_d = 1 + \frac{D_b(K_d)}{n_e}$$

where:  $R_d$  = Retardation factor, no units  
 $D_b$  = Bulk density, grams per cubic centimeter ( $g/cm^3$ )  
 $K_d$  = Distribution coefficient,  $mL_{water}/g_{soil}$   
 $n_e$  = Effective porosity, milliliters water per cubic centimeter soil  
( $mL_{water}/cm^3_{soil}$ )

Total organic carbon was analyzed in soil samples collected from the VW&R facility and results were below the detection limit. TOC analysis was performed on selected soil samples collected during the WCP East Grand Avenue WQARF Site RI. Results indicate that TOC is below the detection limit of 0.07 to 0.12 percent (Table 7-2). The average (arithmetic mean) bulk density is  $1.944 g/cm^3$ . The effective porosity used during the aquifer test was 20 to 30 percent. The following table summarizes the results of the calculations obtained from the above equations for the UAU beneath the WCP East Grand Avenue Site:

Chemical	$K_{oc}$	$f_{oc}^{(1)}$	$K_d$	$R_d^{(2)}$
PCE	303	0.0006	0.18	2.4
TCE	152	0.0006	0.09	1.7
1,1-DCE	217	0.0006	0.13	2.0

<sup>(1)</sup> One-half of the detection limit for TOC was used for the  $f_{oc}$  value.

<sup>(2)</sup>  $R_d$  calculations based on average  $n_e$  of 0.25.

The rate of contaminant movement can be estimated based on the average groundwater velocity and the retardation factor using the following equation:

$$V_c = V/R_d$$

where:  $V_c$  = Contaminant Velocity, ft/day  
 $V$  = Average Groundwater Velocity, ft/day  
 $R_d$  = Retardation factor, no units

An aquifer test was completed on the WCP East Grand Avenue WQARF Site and was described in Section 2.7.3. Average groundwater velocity for the WCP East Grand Avenue was calculated to be 2.4 to 8.6 feet/day (Section 2.7.3.3). Contaminant velocity was calculated for each of the contaminants of concern and is shown in the following table:

<b>Chemical</b>	<b>V (ft/year)</b>	<b>V<sub>c</sub> (ft/year)</b>
PCE	876 to 3139	370 to 1300
TCE	876 to 3139	520 to 1800
1,1-DCE	876 to 3139	440 to 1600

The estimated contaminant migration distance downgradient from the source at the WCP East Grand Avenue WQARF Site can be calculated based on the contaminant velocity and the age of the release. The source of contamination has been identified as being on the VW&R facility and occurring over the length of operation of the facility. VW&R operated at this location from 1956 to 1970. Assuming the age of release is 31 years, the estimated length of the contaminant plume ( $L_c$ ) can be calculated by the following equation:

$$L_c = V_c (\text{Age of release})$$

The estimated contaminant migration distance downgradient from the source at the VW&R facility for PCE, TCE, and 1,1-DCE in the UAU are 11,000 feet, 16,000 feet, and 14,000 feet, respectively. In January 2002, monitoring well WCP-96, located approximately 2,025 feet downgradient from the source area at the VW&R facility, contained PCE and TCE at concentrations of 0.4 mg/L.

Contaminant velocities and estimated length of the contaminant plume should be viewed as qualitative indicators only. As indicated in the data presented above, actual migration rates can vary greatly from these estimates. The above calculations use simplified assumptions and neglect the following potential site-specific effects:

- Vertical and horizontal heterogeneities in hydraulic conductivity, porosity, and TOC in the aquifer material throughout the site.
- Contaminant degradation due to the benzene release at the leading edge of the plume.

- Contaminant degradation due to the SVE system installed at the Southwest Roofing/UPS facility.
- Changes in historical groundwater flow direction and therefore, contaminant migration, due to historical pumping of the SRP wells 10.5E-7.5N and 11.2E-7.5N.
- Changes in groundwater flow direction due to lining of the Grand Canal.
- Changes in groundwater gradient due to removal of recharge resulting from lining the Grand Canal (i.e., the groundwater gradient was more flat prior to lining the Grand Canal than the current gradient).
- Changes in groundwater gradient due to regional reductions in groundwater levels resulting from protracted drought conditions.
- Declining groundwater elevation and subsequent sorption of contaminants to the capillary fringe area and/or to the mineral phase of the aquifer material.