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TECHNICAL MEMORANDUM

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Assessment and Remediation of Vapor Intrusion to Indoor Air, South Mesa State Superfund Site in Gilbert, Arizona

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Abstract

Vapor intrusion to indoor air from volatile organic compound (VOC) contamination in the subsurface is increasingly becoming a more important exposure pathway when developing site conceptual models and ultimately obtaining site closure. Until recently, this exposure pathway was not often considered during site characterization. The direct measurement of the vapor intrusion to indoor air pathway is typically difficult to perform due to sample collection methods and interferences to samples such as ambient air. In order to perform valid measurements, a thorough understanding of the site and use of multiple characterization tools are necessary. A cost effective three-phase approach to assess the vapor intrusion to indoor air pathway at the South Mesa Water Quality Assurance Fund (Arizona State Superfund or WQARF) Registry site in Gilbert, Arizona was implemented.

Introduction

Site Description

The subject site is a former metal plating facility located within the boundaries of the South Mesa Water Quality Assurance Revolving Fund (Arizona State Superfund) Registry Site (SMWRS). In 1983, PCE was detected in an irrigation well located approximately 500 ft (152 m) downgradient of the site and was immediately taken off-line, though it was periodically sampled. The well operated as a containment pump-and treat well from 1994 to 1997, after which the well was permanently taken off-line. In 1985, a sample collected from the irrigation well contained 780 ug/L of PCE. A second irrigation well, located approximately 1.5 mi (2.4 km) downgradient of the site, also had detections of PCE. Preliminary investigation, involving sampling of production wells and the installation of 10 monitoring wells, identified an approximate 1.5 mi long (2.4 km) by 0.5 mi (0.8 km) wide PCE groundwater plume apparently originating from the subject site (Figure 1 next page).

Figure 1 – Subject Site

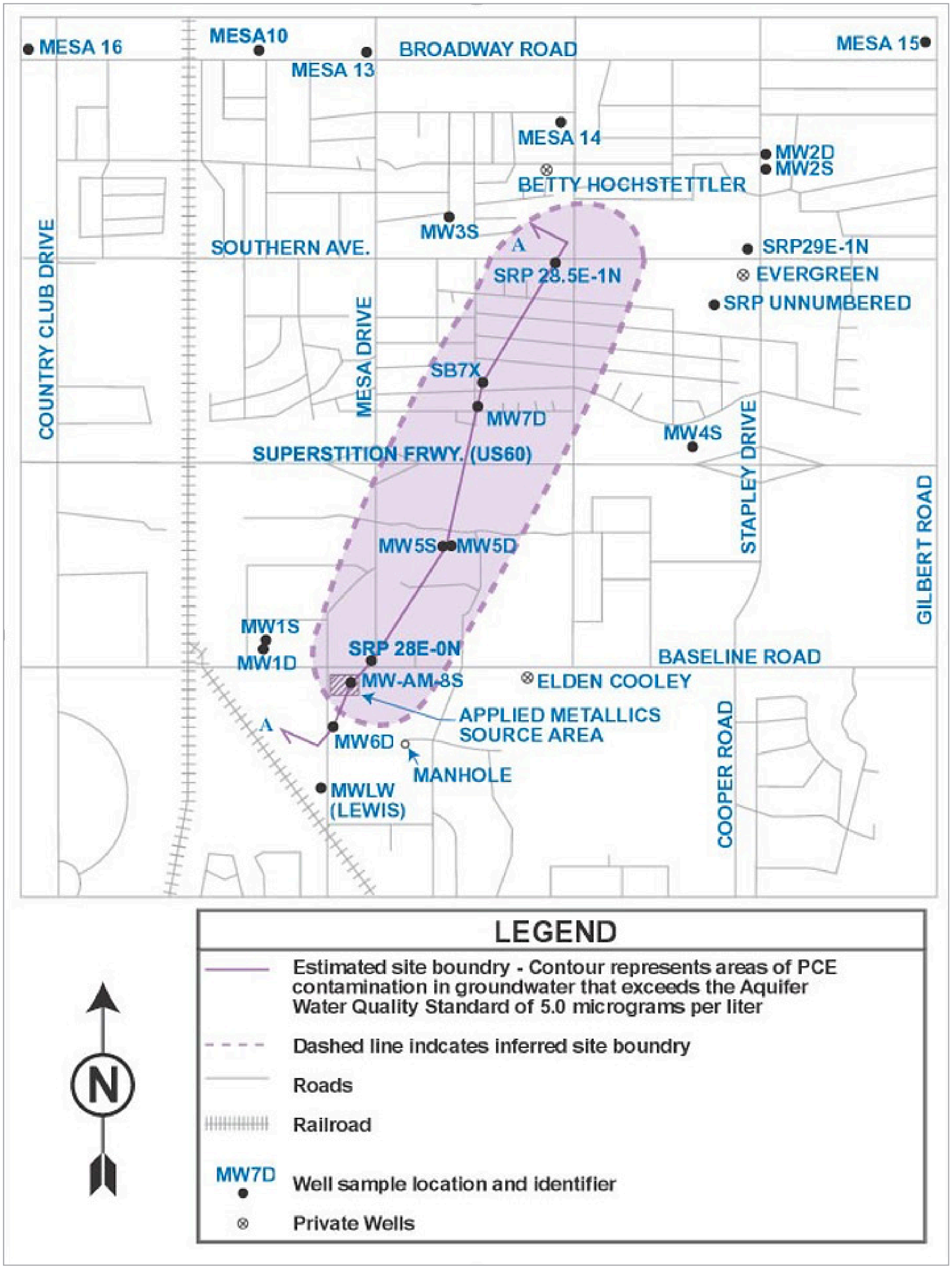


Figure 2 – Site Plan

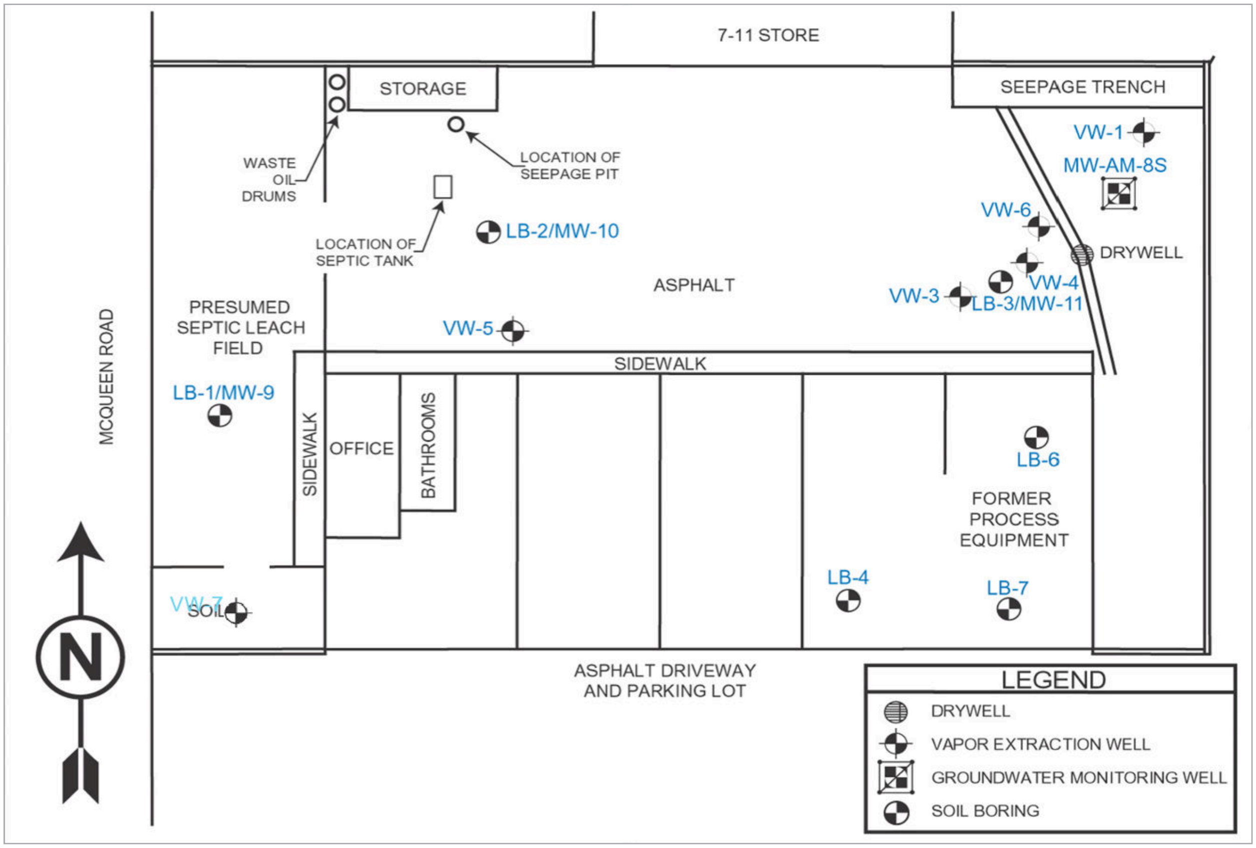


Figure 2 shows a site plan of the former metal plating facility. PCE and metal wastes were discharged to an on-site injection well from approximately 1979-1988. Other possible sources of contamination were a septic system and leakage from processing equipment. While the metal plating facility was in operation, groundwater was as deep as 200 ft (61 m) bgs. However, due to decreased groundwater usage in the area, the water table has risen to its current level of approximately 115 ft (35 m) bgs-a rise of 85 ft (26 m). An on-site monitor well (MW-AM-8S) installed in 1991 to a depth of 165 ft (50 m) contained PCE concentrations ranging from 10 ug/L to 300 ug/L. Monitor well MW7D, located approximately one-mile down-gradient of the site, has consistently contained PCE concentrations ranging from 8 ug/L to 60 ug/L since the time of its installation in 1991. Previous site investigation and source removal activities were focused on the injection well and approximately 1,100 lbs (500 kg) of volatile organic compounds (VOCs) were removed by Soil Vapor Extraction (SVE) from 1995-1997.

Vapor Intrusion Assessment Methods

A remedial investigation (RI) and early response action (ERA) of the SMWRS for the Arizona Department of Environmental Quality (ADEQ) was completed. As part of the RI, vapor intrusion to indoor air was assessed. The lithology (adundance of cobbles) below the site prevented the use of lower cost characterization tools, such as direct-push technologies. Therefore, an innovative approach was utilized to minimize the number of borings and costs. The vapor intrusion assessment involved five phases as follows: 1) surface geophysical survey; 2) passive soil vapor survey; 3) collection of discreet soil and soil gas samples from deep borings; 4) collection of discrete soil and soil gas samples from shallow borings; and, 5) collection of indoor air quality (IAQ) samples. The objectives of the vapor intrusion assessment are listed as follows: 1) identify potential source areas; 2) characterize the vadose zone below the site; 3) obtain vertical contaminant profiles; 4) confirm operation of the SVE system; 5) evaluate potential health risks associated with vapor intrusion; and, 6) minimize costs.

Geophysical Survey

A surface geophysical survey consisting of a combination of electromagnetics and ground penetrating radar (GPR) was performed on May 14, 2001 to identify the location of an on-site septic tank and associated leach pit.

Passive Soil Vapor Survey

Based on the results of the geophysical survey and a review of historic site plans, a passive soil vapor survey using Passive Soil Gas (PSG) samplers provided by Beacon Environmental (Beacon) was performed to obtain a surficial representation of the subsurface PCE contamination. The passive soil gas survey was performed from May 24, 2001 through May 31, 2001. A survey grid consisting of 40 sample points was designed (Figure 4), with the sample points concentrated around the former injection well, at the former process equipment area, and at the septic tank. The PSG sampler, which consists of sorbent materials, was installed approximately 8 in (20 cm) bgs for 72 hours. The results were time-weighted and spatially variable soil gas masses that took into account soil vapor concentration changes and other vapor transport processes.

Deep Borings

The PCE results for the passive soil vapor survey are shown on Figure 5. Based on the passive soil vapor survey results, deep soil borings LB-1 (southwest corner), LB-2 (septic tank), and LB-3 (injection well) were drilled from August 20, 2001 through August 31, 2001. The borings were intended to evaluate the extent of VOC impact within the UAU. Therefore, the maximum drilling depth was 240 ft (73 m) bgs. The borings were drilled using an AP-1000 dual-wall percussion drill rig. In order to obtain vertical contaminant profiles, discrete soil and soil vapor samples were collected using the Maxisimulprobe (MSP) system. The MSP system allows the collection of discrete soil and soil vapor samples or discrete soil and groundwater samples in one tool, that are analyzed on-site. The selected sampling depths were based on the lithology of the site. All samples were submitted to an on-site mobile laboratory and PCE, TCE, and 1,2-DCE using EPA Method 8021 were reported. The mobile laboratory was used to obtain rapid analytical results, thus minimizing drilling delays. The mobile laboratory typically provided analytical results within 30 minutes of sample collection.

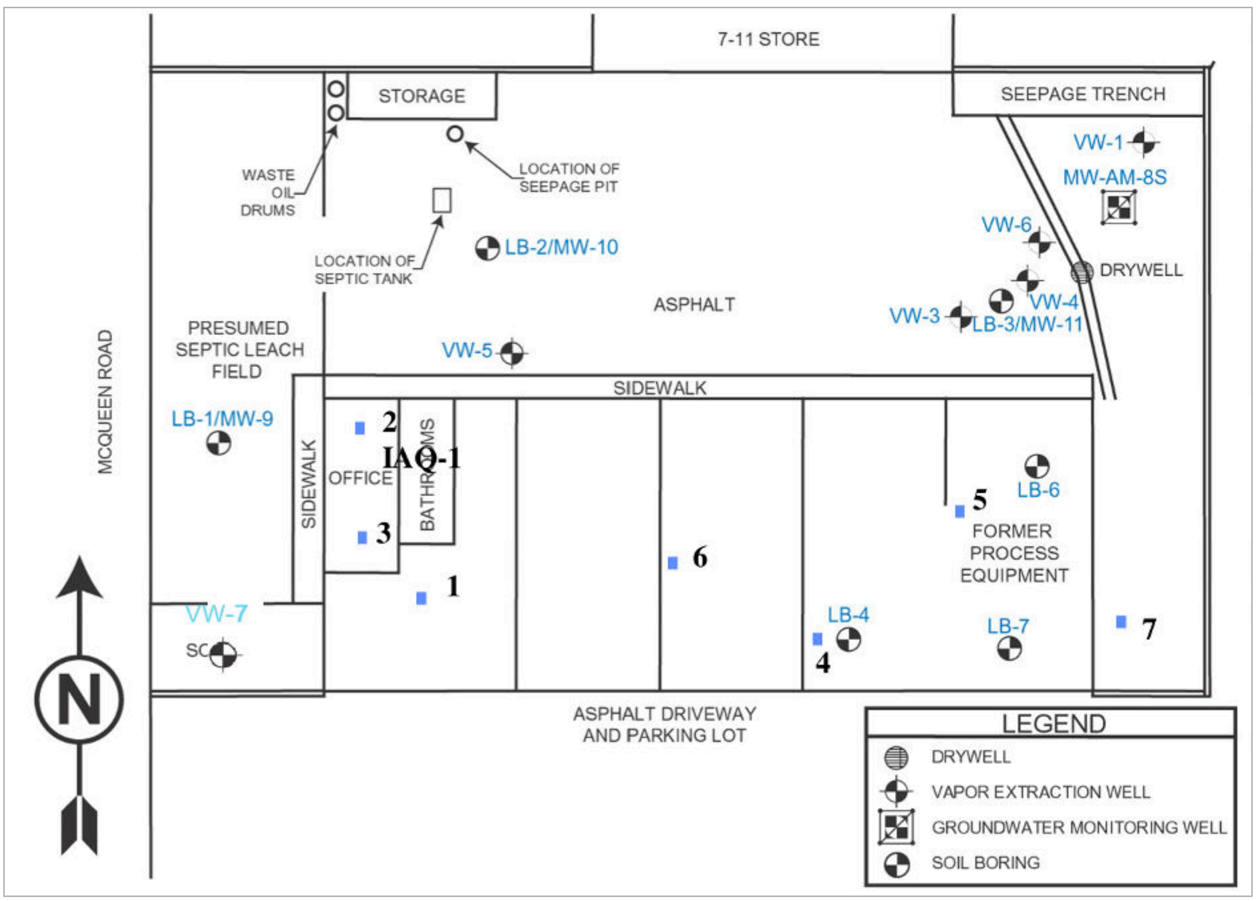
Shallow Borings

Borings LB-4, LB-6 and LB-7 were drilled from September 11, 2001 through September 13, 2001. The locations are shown on Figure 3. These borings were intended to evaluate the vadose zone impact below the former process equipment area. The borings were drilled inside the structure, because the drilling method was limited to low-profile hollow-stem auger. Very dense cobbles and gravels are present at approximately 62 ft (19 m). Therefore, drilling and sampling was limited to 60 ft (18.3 m) bgs. During drilling, discrete soil and soil gas samples were collected at 10-ft (3 m) intervals using the Maxisimulprobe system.

Indoor Air Quality Sampling

The results of the passive soil vapor survey and subsurface investigation indicated a PCE soil vapor plume was present beneath the building. Therefore, vapor intrusion to indoor air was considered a potential exposure pathway at the site. ADEQ approved the use of indoor air quality (IAQ) sampling to evaluate vapor intrusion into the site building. Two rounds of vapor sampling were performed; the first on June 27, 2002 and the second on December 17, 2002. The IAQ sample locations are shown on Figure 3. The IAQ sampling involved the placement of summa-canisters at six locations within the building. Sample 7 was collected outdoors as an ambient air sample. The summa canisters were under vacuum and a regulator was set to collect an eight-hour draw sample. The samples were analyzed for VOCs using EPA Method TO-15. Samples 1 through 3 collected on June 27, 2002 were collected in a vacant office suite. During the interim, the vacant space became a sales business (Suite 1) and was operating as such on the December 17, 2002 sampling event.

Figure 3 – IAQ Sample Locations

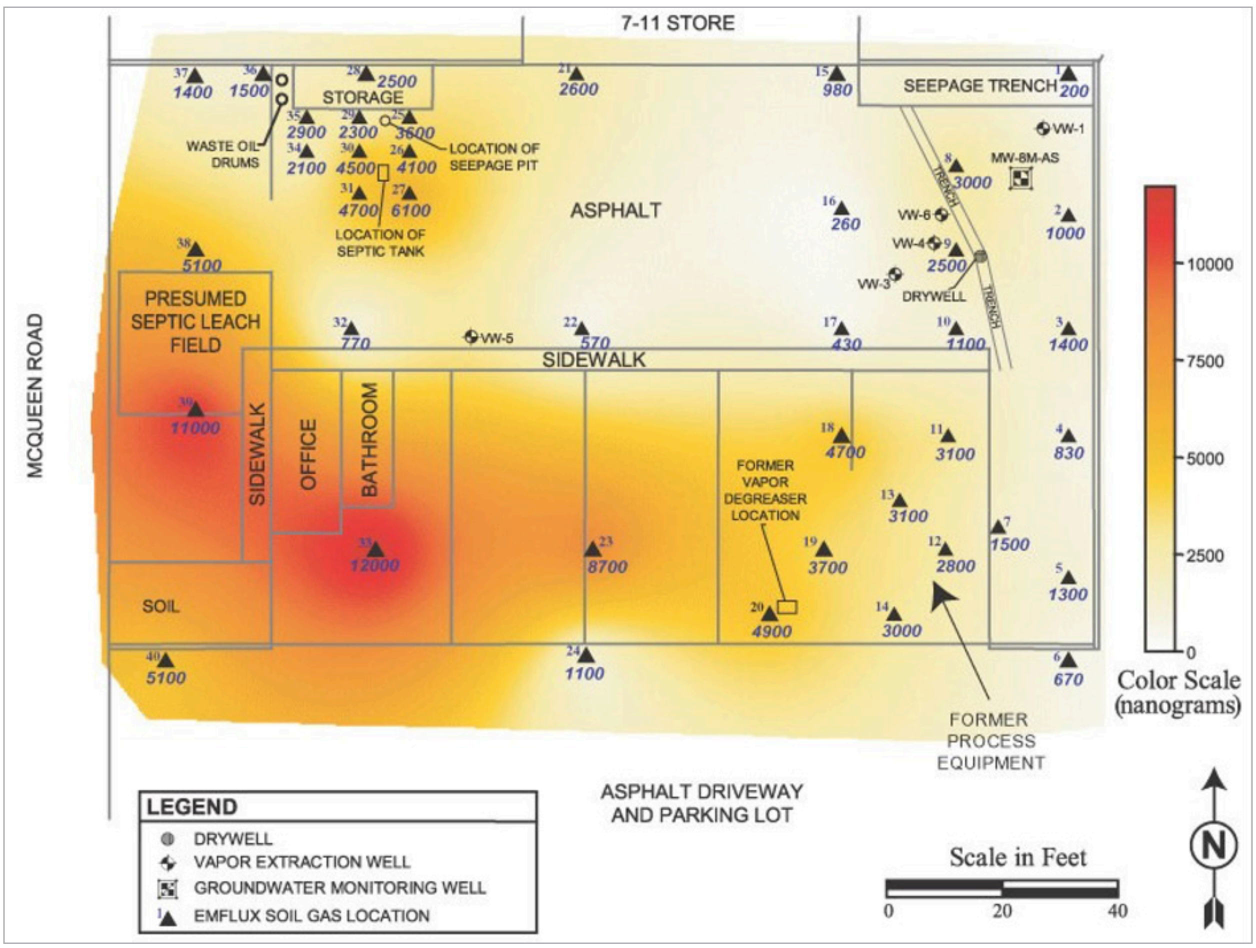


Vapor Intrusion Assessment Results

Passive Soil Vapor Survey

The PCE results for the passive soil gas survey are shown on Figure 4, which is a concentration isopleth map that illustrates the spatially varying mass of PCE in the soil gas. PCE concentrations ranged from 200 ng to 12,000 ng, with a mean concentration of 3,078 ng. The PSG samplers located in the southwest corner of the site showed the highest PCE masses, which indicated a possible PCE vapor plume beneath the west side of the building and directly below Suite 1.

Figure 4 – PCE Passive Soil Vapor Survey Results

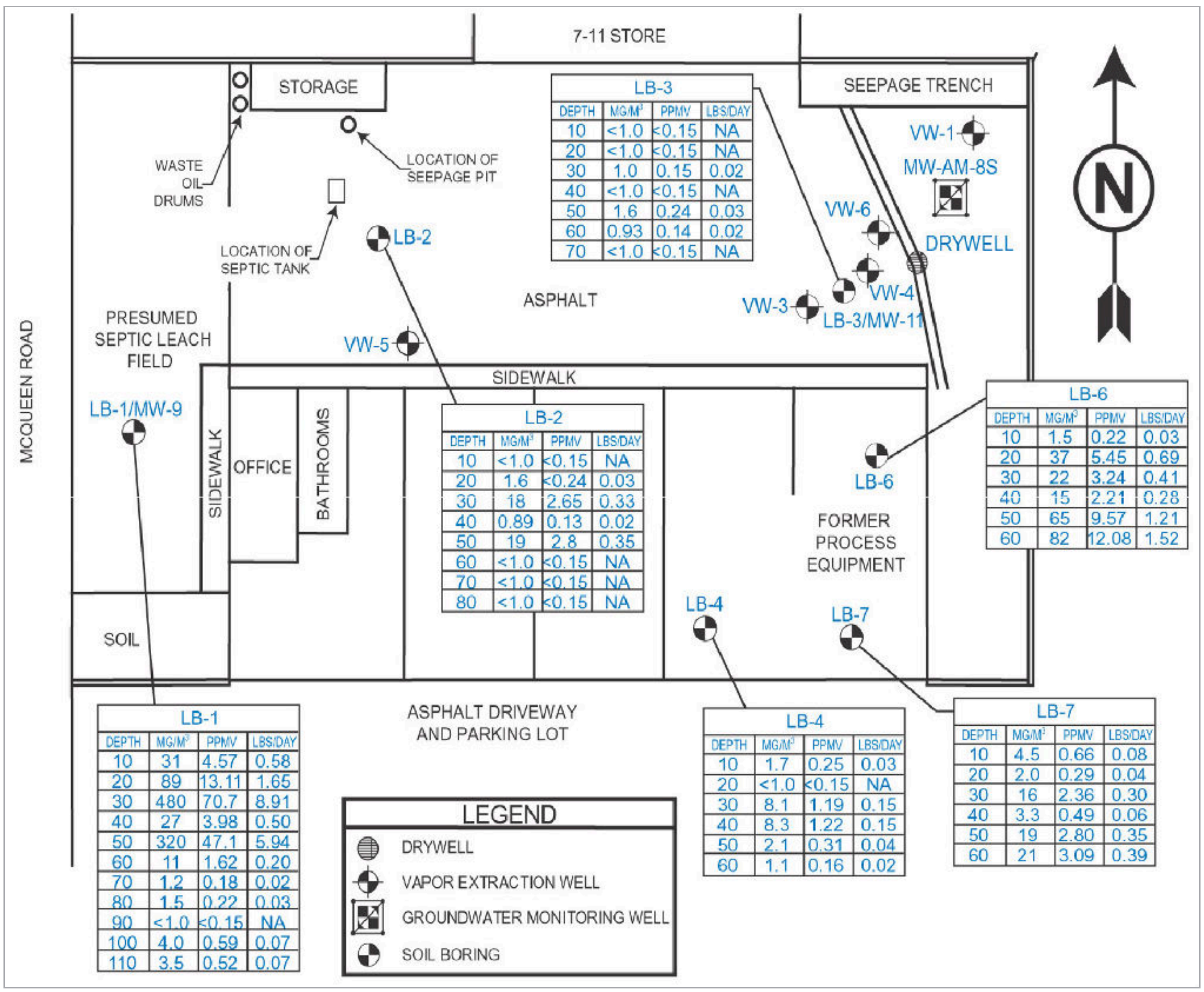


Soil Gas and Soil Samples

The discrete soil gas samples were analyzed for PCE, TCE, and 1,2-DCE and the soil samples were analyzed for VOCs, arsenic, total chromium, hexavalent chromium, copper, cyanide, nickel and zinc. The discrete soil samples contained non-detectable concentrations of VOCs and concentrations of metals and cyanide that were below the Arizona minimum soil cleanup levels.

However, the discrete soil gas samples contained relatively high concentrations of PCE, particularly the samples collected from borings LB-1 and LB-6 (Figure 6). The samples collected between 30 and 50 ft (9-15 m) bgs, which is a predominantly sandy interval, contained the highest PCE concentrations. PCE mass removal rates assuming a soil vapor extraction flow rate of 200 scfm, are also shown on Figure 5.

Figure 5 – PCE Soil Gas Concentration with Depth



Sample No.	Location	Date	PCE[a]			TCE[b]			Combined CILCR[d]
			ppbv	ug/m³	CILCR[c]	ppbv	ug/m³	CILCR[c]	
1	Suite 1 Floor	6/27/02	20	135.6	9E-07	0.97	5.21	1E-06	2E-06
		12/17/02	13	88.14	6E-07	1.2	6.44	2E-06	3E-06
2	Suite 1 Office	6/27/02	57	386	3E-06	0.94	5.05	1E-06	4E-06
		12/17/02	180	1220.4	9E-06	4.0	21.48	6E-06	2E-05
IAQ-1		**11/21/07**	0.85	5.9	**4E-08**	<0.5	<2.8	NA	**4E-08[e]**
3	Suite 1 Mezzanine	6/27/02	16	108.48	8E-07	0.81	4.35	1E-06	2E-06
		12/17/02	17	115.26	8E-07	0.78	4.19	1E-06	2E-06
4	Suite 4 Floor	6/27/02	<0.50	<3.39	NA	<0.50	<2.69	NA	NA
		12/17/02	NS	NS	NS	NS	NS	NS	NS
5	Suite 5 Floor	6/27/02	2.0	13.56	9E-08	<0.50	<2.69	NA	9E-08
		12/17/02	NS	NS	NS	NS	NS	NS	NS
6	Suite 3 Floor	6/27/02	5.5	37.29	3E-07	0.76	4.08	1E-06	1E-06
		12/17/02	7.0	47.46	3E-07	0.61	3.28	9E-07	1E-06
7	Outside	6/27/02	<0.50	<3.39	NA	<0.50	<2.69	NA	NA
		12/17/02	<0.50	<3.39	NA	0.67	3.60	1E-06	1E-06
EPA Region 9 PRG[f]			0.099	0.32	NA	0.003	0.017	NA	NA
Commercial PRG			**21.09**	**143**	**NA**	**0.667**	**3.58**	**NA**	**NA**
ILCR Acceptable Exposure Standard[g]			NA	NA	1E-04	NA	NA	1E-04	1E-04
ILCR de minimus Exposure Standard			NA	NA	1E-06	NA	NA	1E-06	1E-06

a. PCE results reported in parts per billion of vapor volume (ppbv) and
b. micrograms per cubic meter (ug/m³). NS – not sampled.
c. TCE results reported in parts per billion of vapor volume (ppbv) and micrograms per cubic meter (ug/m³). NS – not sampled.
d. CILCR – Commercial Incidental Lifetime Cancer Risk. NA indicates not applicable due to laboratory non-detect concentrations.
e. Combined CILCR = PCE CILCR + TCE CILCR.
f. The combined CILCR for sample IAQ-1 collected on 11/21/07 does not exceed 1E-06. Therefore, according to the National Contingency Plan (NCP) no further action is required.
g. Environmental Protection Agency (EPA) Region 9 Preliminary Remediation Goal (PRG) for ambient air (EPA 2004).
h. Incremental Lifetime Cancer Risk (ILCR) acceptable exposure standard per the NCP.

The individual and combined ILCRs for PCE and TCE did not exceed the acceptable exposure standard of 1x10-4, because the combined ILCR exceeded 1x10-6, ADEQ decided to proceed with an early response action (ERA) to remove the source of the vapor intrusion to the Suite 1 office.

Remedial Activities

In July 2004, a nested vapor extraction well was installed in the southwest corner of the site, identified as VW-7 on Figures 2 and 3. The approximate radius of influence (ROI) for a vapor well at the site was determined to be approximately 60 ft (18m). Therefore, VW-7 was installed at a location where the ROIs for VW-5 and VW-7 would overlap beneath the building. VW-5 and VW-7 were connected to the existing SVE system located in the eastern portion of the site. The SVE system was started in September 2004. The remedial goal was to reduce PCE and TCE concentrations in the Suite 1 office to an ICLR less than 1x10-6. Influent PCE concentrations at the start of operation in September 2004 were 310,000 micrograms per cubic meter (ug/m^3). SVE system operation continued to August 2007 when asymptotic vapor concentrations between 950 ug/m^3 and 1,100 ug/m^3 had been achieved. On November 21, 2007, an IAQ sample identified as IAQ-1 on Figure 3 and on Table 1 was collected from the Suite 1 office. As shown in Table 1, the PCE concentrations in the Suite 1 office was reduced to 5.9 ug/m^3 from a high of 1,220.4 ug/m^3 on December 17, 2002. TCE was not detected in the November 21, 2007 sample. The combined ILCR is 4x10-8, which is less than the 1x10-6. Therefore, ADEQ subsequently approved completion of the ERA.

Conclusions

The passive soil vapor survey proved to be a cost effective, rapid and accurate method to delineate the areal extent of the vadose zone impact and identify possible source areas. The passive soil vapor survey also indicated the area of the site where vapor intrusion was a potential exposure pathway. The follow-up depth-specific soil gas and IAQ sampling programs confirmed the results of the passive soil vapor survey. The operation of the SVE system as an ERA successfully reduced the PCE and TCE concentrations in the Suite 1 office to below the established cleanup goal.

References

USEPA, 1990, ***National Oil and Hazardous Substances Pollution Contingency Plan***, 40 CFR Part 300; Federal Register, Volume 55, No. 46, pp. 8666-8865, Washington, DC, Thursday, March 8.

USEPA, 2004. ***Region 9 Preliminary Remediation Goals (PRGs) 2004***, December 28, 2004.