Application of Passive Soil Gas Technology to Determine the Source and Extent of a PCE Groundwater Plume in an Urban Environment

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In situations where groundwater supplies have been impacted by volatile organic compounds (VOCs), such as tetrachloroethene (PCE), and the source has not been identified, the costs to identify the source and plume migration patterns may be extremely high. The costs for an investigation increase with the number and depth of borings and the number of samples that are collected and analyzed. An environmental investigator and the Arizona Department of Environmental Quality (ADEQ) have successfully utilized passive soil gas (PSG) surveys in Arizona to cost-effectively investigate VOC impacts to groundwater and identify potential sources of impact. PSG surveys are minimally intrusive, and more samples can be collected for the same cost when compared to active soil gas surveys and conventional soil and groundwater sampling programs. The result is a surficial representation of the contaminant plume and the location of "hot spots," which are the potential sources. This provides a better understanding of the nature and extent of the impact and allows for a focused subsurface investigation, which subsequently reduces drilling and sampling costs.

INTRODUCTION

Site Description

The subject site is known as the Miller Valley Road and Hillside Avenue Water Quality Assurance Revolving Fund (WQARF) Preliminary Investigation (PI) site in Prescott, Arizona (see Exhibit 1). Tetrachlorothene (PCE) was detected above the groundwater cleanup level of 5.0 μg/L in a monitoring well at a former gas station at the southeast corner of Miller Valley Road and Hillside Avenue. The Arizona Department of Environmental Quality (ADEQ) subsequently authorized a PI to identify the source of the PCE. A dry cleaning facility is located approximately 0.25 mi (0.40 km) to the west of the monitoring well and was a suspected source of the PCE. The environmental investigator reviewed building plans for the dry cleaning facility and found that the current facility was constructed in 1988. However, the facility had moved from its previous location that was

Published online in Wiley Interscience (www.interscience.wiley.com). DOI: 10.1002/rem.20182

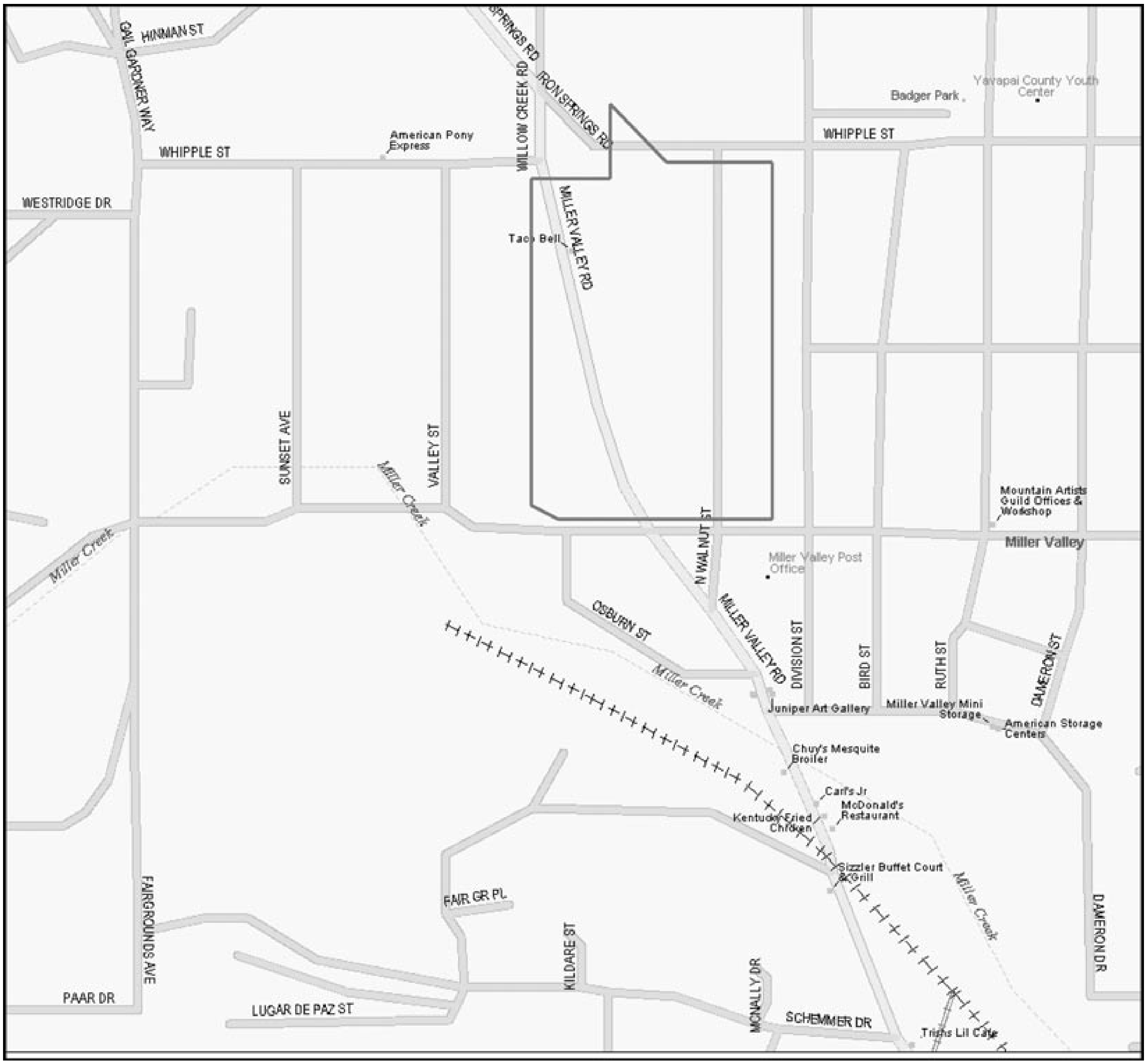

Exhibit 1. Site location

across Hillside Avenue to the north, where it had operated since the 1960s (see Exhibit 2). There were also other potential sources of PCE in the area.

Hydrogeology

Based on the review of available information for the study area, the lithology underlying the site was expected to consist primarily of relatively soft silt and clay. Depth to groundwater was expected to range in depth from 8 feet (2.4 meters) to 18 feet

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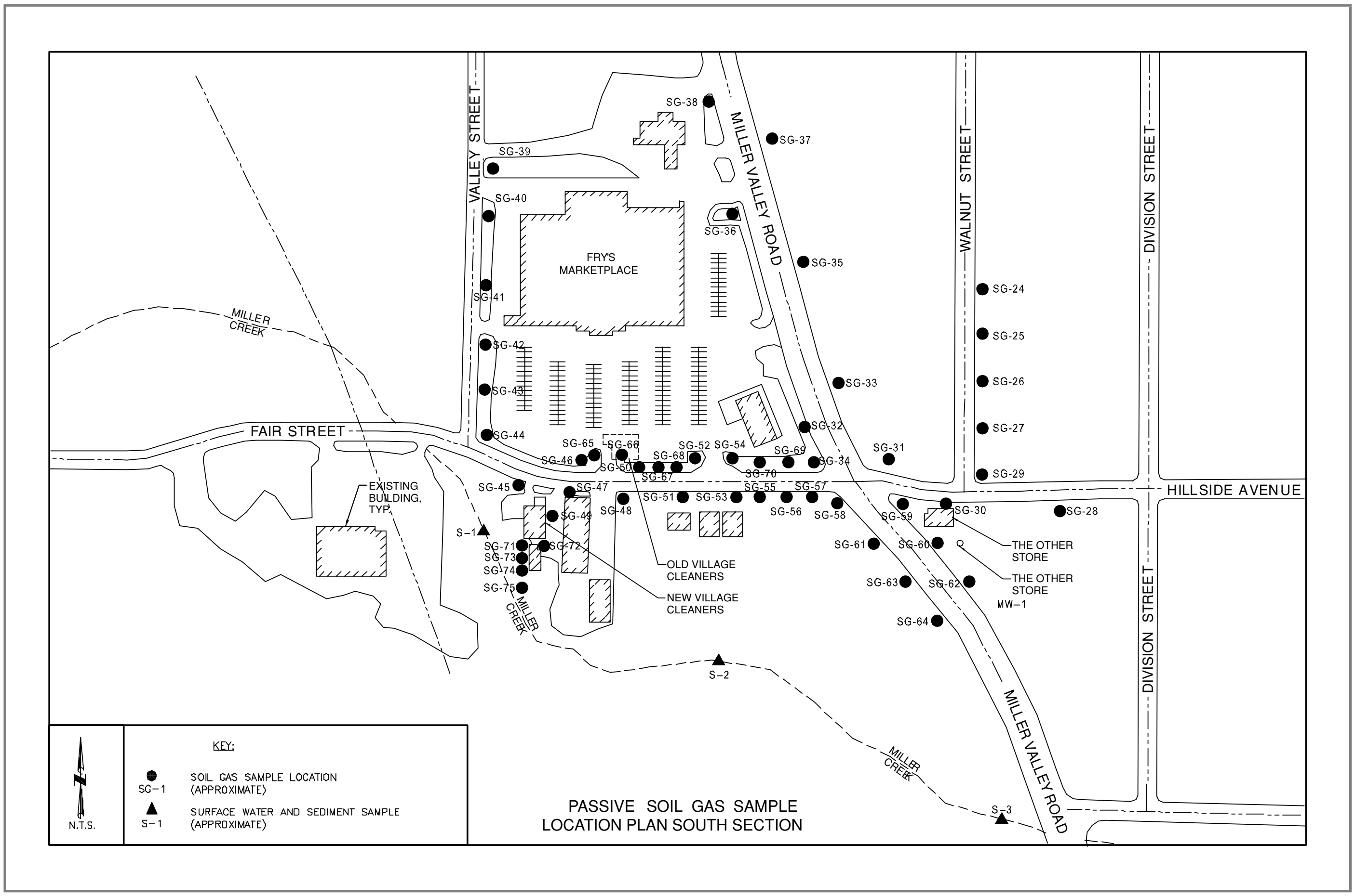

Exhibit 2. Site plan

(5.5 meters) below ground surface (bgs), and groundwater was expected to flow in an easterly direction. The lithology encountered during drilling of 11 confirmatory borings consisted primarily of decomposed or fractured granitic bedrock. This unit is water-bearing and will eventually yield water to a well. Recovery of water to the piezometric surface in the borings drilled at the site ranged from less than 30 minutes to more than 24 hours. Water was not yielded in borings HP-2 (9 feet [2.7 meters] bgs) and HP-16 (8 feet [2.4 meters] bgs). Water was yielded in borings HP-1, HP-3, HP-4, HP-5, HP-6, HP-7, HP-10, HP-12, and HP-13. Depth to water ranged from 4.2 feet (1.3 meters) in HP-7 to 12.6 feet (3.8 meters) in HP-10.

METHODS

The PI was conducted in two phases. Phase 1 involved a passive soil gas survey, and Phase 2 involved a limited confirmatory groundwater investigation. The methods utilized are summarized in the sections that follow.

Exhibit 3. BeSure PSG sampler

Passive Soil Vapor Survey

A high-resolution, passive soil vapor survey was performed to obtain a surficial representation of the subsurface PCE contamination. The environmental investigator obtained a BeSure Sample Collection Kit from Beacon Environmental Services, Inc., shown in Exhibit 3, to collect samples and then submitted the samples to Beacon for analysis. Passive soil gas (PSG) surveys are ideal for measuring a wide range of volatile organic compounds (VOCs) in a broad range of geologic formations materials. An advantage of PSG surveys is that the method allows for long exposure times that allow for the sorbents to be in contact with the organic gas or vapor to maximize the diffusive transport mechanism, as discussed in American Society for Testing and Materials (ASTM) D 5314-92 (2006). The PSG survey was performed from August 31, 2005, through September 15, 2005. A survey grid consisting of 50 sample points was designed (Exhibit 2), with the sample points concentrated around the current and former locations of the dry cleaning facility. Each BeSure sampler, which contains two sets of engineered adsorbent cartridges within a small vial, was installed approximately 8 inches (20 cm) bgs for approximately two weeks. The result was a time-weighted soil gas measurement that normalizes the daily and hourly soil vapor concentration changes that are known to occur. The samplers were retrieved on September 15, 2005, approximately two weeks after installation. The samples were analyzed by Beacon for PCE, trichloroethene (TCE), and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) using US EPA Method 8260B.

Limited Confirmatory Groundwater Investigation

Based on the results of the passive soil vapor survey, which are shown in Exhibit 4, a limited confirmatory groundwater investigation was performed. A total of 11 soil borings were advanced at the site. The boring locations, shown in Exhibit 4, were based on the results of the passive soil vapor survey and available property access. A total of 16 borings, identified as HP-1 through HP-16, were originally planned. From November 1, 2005, through November 2, 2005, borings HP-1, HP-5, HP-6, HP-7, HP-8, HP-12, and HP-16 were advanced using the direct-push technology (DPT). Water samples were successfully collected from borings HP-6 (5.0 feet [1.5 meters]) and HP-7 (4.2 feet [1.3 meters]).

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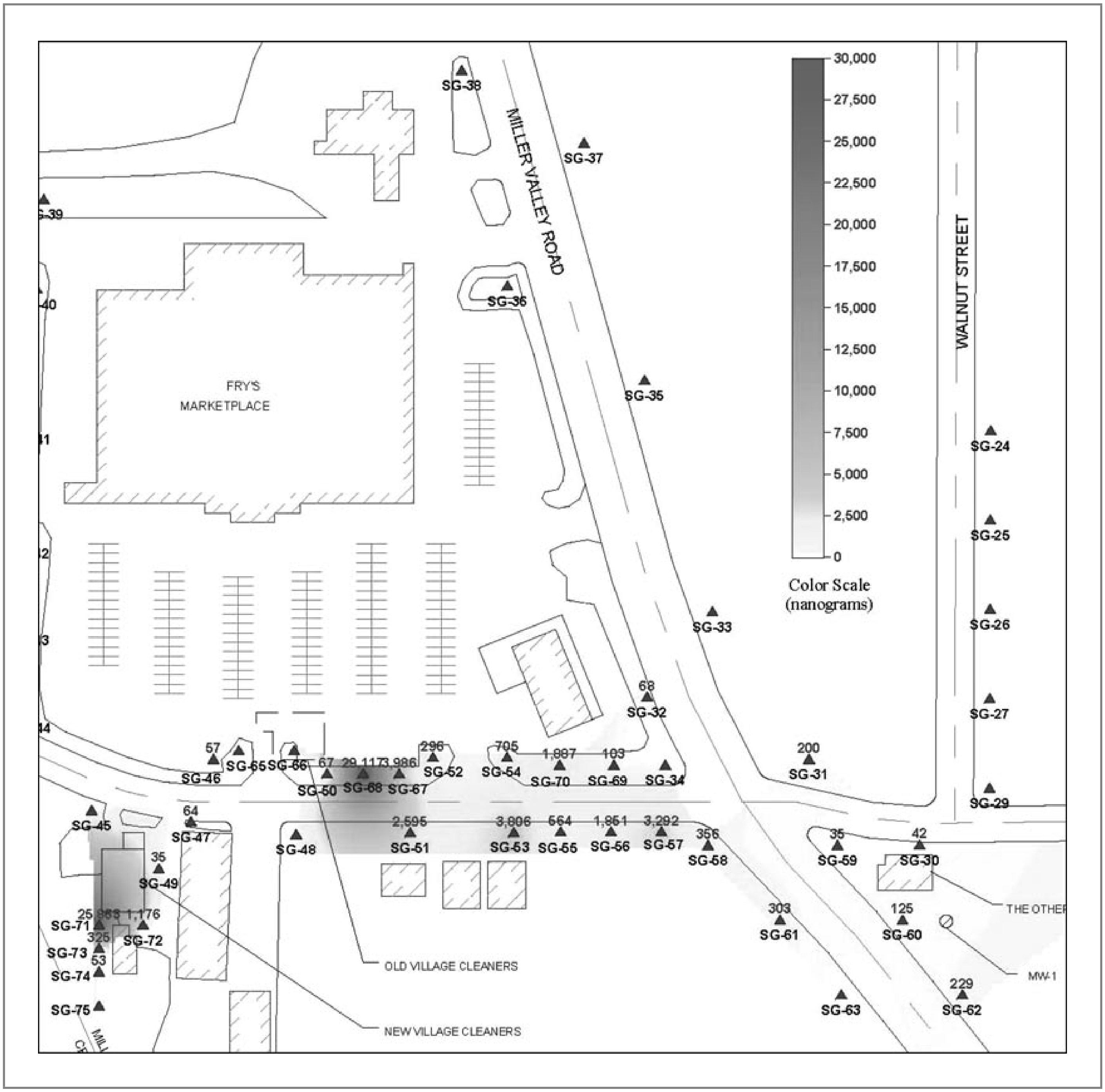

Exhibit 4. Results of passive soil vapor survey

Refusal occurred in the other borings before water was encountered. Therefore, from November 28, 2005, through November 30, 2005, borings HP-1, HP-2, HP-3, HP-4, HP-5, HP-10, HP-12, and HP-13 were advanced using a hollow-stem auger (see Exhibit 5). Access was not granted for borings HP-8 and HP-16, and it was decided in the field not to drill borings HP-9, HP-11, HP-14, and HP-15. Access to sample two private production wells was granted, which eliminated the need for borings HP-8 and HP-9.

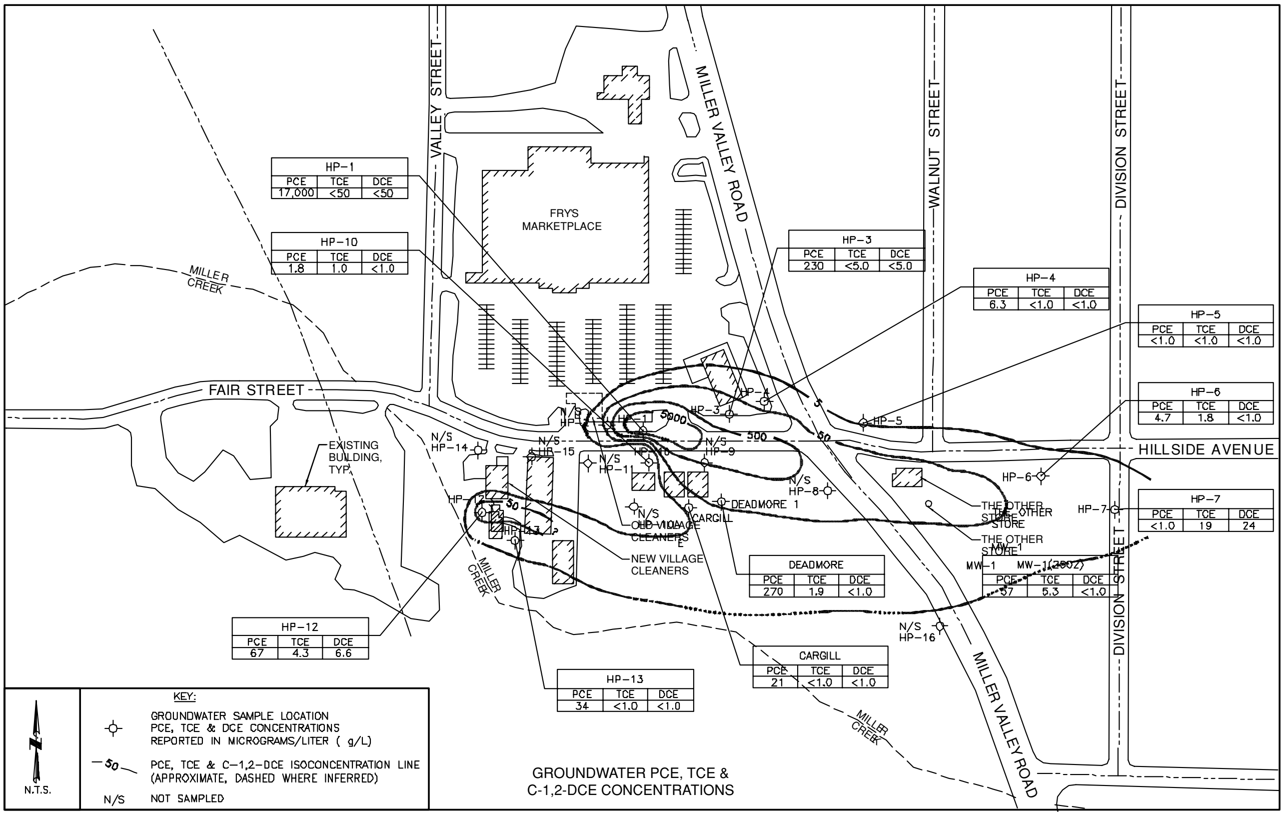

Exhibit 5. Groundwater sample locations and results

Groundwater samples were successfully collected from borings HP-1, HP-3, HP-4, HP-5, HP-10, HP-12, and HP-13. Auger refusal occurred in boring HP-2, and a groundwater sample was not successfully collected. The groundwater samples were analyzed for VOCs using US EPA Method 8260B.

RESULTS AND DISCUSSION

Passive Soil Vapor Survey

The PCE results for the passive soil gas survey are shown in Exhibit 4, which includes a PCE isopleth map. The BESURE method reports the quantity of target VOC sorbed to the sampler. When plotted on an isopleth map, potential source areas and groundwater migration patterns are indicated. Within the study area, PCE concentrations ranged from nondetect (less than 25 ng) to 29,117 ng. A previous groundwater sample collected from MW-1, which is shown in the southeast corner of Exhibit 5, contained a PCE concentration of 6.8 μg/L. Sample SG-60 contained 125 ng of PCE. Therefore, passive soil vapor samples detected with greater than 125 ng of PCE were likely installed above groundwater impacted with greater than 6.8 μg/L of PCE. Potential sources of PCE impact to the groundwater were identified at samples SG-68 (29,117 ng of PCE) and

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SG-71 (25,863 ng of PCE). The BeSure samplers indicated the presence of a possible groundwater PCE plume extending from sample locations SG-68 and SG-71 east toward SG-60.

Limited Groundwater Investigation

Grab groundwater samples were collected from 11 borings, and water samples were collected from two monitoring wells. The results of the groundwater investigation are shown in Exhibit 5.

Samples HP-1 and HP-12 were collected at potential source locations as indicated by the passive soil gas survey results. Samples HP-1 and HP-12 contained 17,000 μg/L and 67 μg/L of PCE, respectively. The HP-12 groundwater source area appears to have a substantially lower concentration than the HP-1 source area. HP-12 was collected in the vicinity of the new dry cleaner, while HP-1 was collected near the historic dry cleaner. It is likely that the contamination measured at location SG-71 is from soil contamination as well as from the groundwater. Plotting of total PCE, TCE, and *cis*-1,2-DCE isoconcentration lines indicates two PCE plumes that commingle. The commingled plume extends for a currently unknown distance downgradient of the two sources.

CONCLUSIONS

The investigation was very effective in identifying the source of PCE in the gas station's monitoring well. The investigation was also successful in delineating the lateral extent of the PCE plume and the migration pathway. The PSG survey proved to be a cost-effective method to identify the source areas and the extent of the PCE plume. A minimal number of soil borings to collect grab groundwater samples was required to confirm the results of the passive soil vapor survey, thus minimizing costs. A PSG survey should be a very effective tool in identifying source areas and delineating groundwater plumes in similar scenarios such as the site or where groundwater is deeper and PCE concentrations vary considerably across a site or region. For this site, a PSG sample with a detection of 100 ng of PCE should indicate the presence of groundwater impacted with PCE near the groundwater cleanup level of 5.0 μg/L.

REFERENCES

American Society for Testing and Materials (ASTM). (2006). Standard guide for soil gas monitoring in the vadose zone. ASTM D 5314-92. West Conshohocken, PA: Author.

James N. Clarke is a principal geologist in the Phoenix office of MACTEC Engineering and Consulting, Inc. He has an MSE in civil engineering from Arizona State University and a BS in geology from Northern Arizona University. Clarke has 19 years of experience in site characterization, remedial investigations (RIs), remedial/corrective action plans, risk-based closure, and remedial design. He has managed RIs under the Arizona Department of Environmental Quality (ADEQ) Water Quality Assurance Revolving Fund program and underground

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Deborah F. Goodwin has both a BS in microbiology and an MS in environmental technology management from Arizona State University. She has been with the Arizona Department of Environmental Quality since 1987 and in the Waste Programs Division since 1992, specializing in site characterization. Her current duties are project management/hydrologist for the state Superfund and the federal Brownfields programs.

Harry O'Neill is the president of Beacon Environmental Services and has managed soil gas investigations for 17 years for the Department of Defense, Department of Energy, and commercial markets. He continues to be at the forefront of passive and active sorbent technologies at the national and international level and has implemented the technologies at thousands of sites. He received his BA from Loyola College in Maryland.

Joseph E. Odencrantz, PhD, P.E., is technical director and western region manager for Beacon Environmental Services, Inc. (www.beacon-usa.com). Dr. Odencrantz is a recognized expert in site investigation and remediation, fate-and-transport processes, and forensic evaluations. He obtained his MS and PhD in civil and environmental engineering from the University of Illinois at Urbana-Champaign and his BS in civil engineering from the University of Maine at Orono. He has published extensively on fate-and-transport of organics in surface and groundwater systems, natural attenuation, cleanup levels, policy, and the treatment of affected water bodies. Dr. Odencrantz was also a visiting professor at the Research Center for Environmental Quality Management at Kyoto University from January through June 2007.

Remediation DOI: 10.1002.rem