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TECHNICAL MEMORANDUM

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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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Abstract

In situations where groundwater supplies have been impacted by volatile organic compounds, such as perchloroethylene (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.

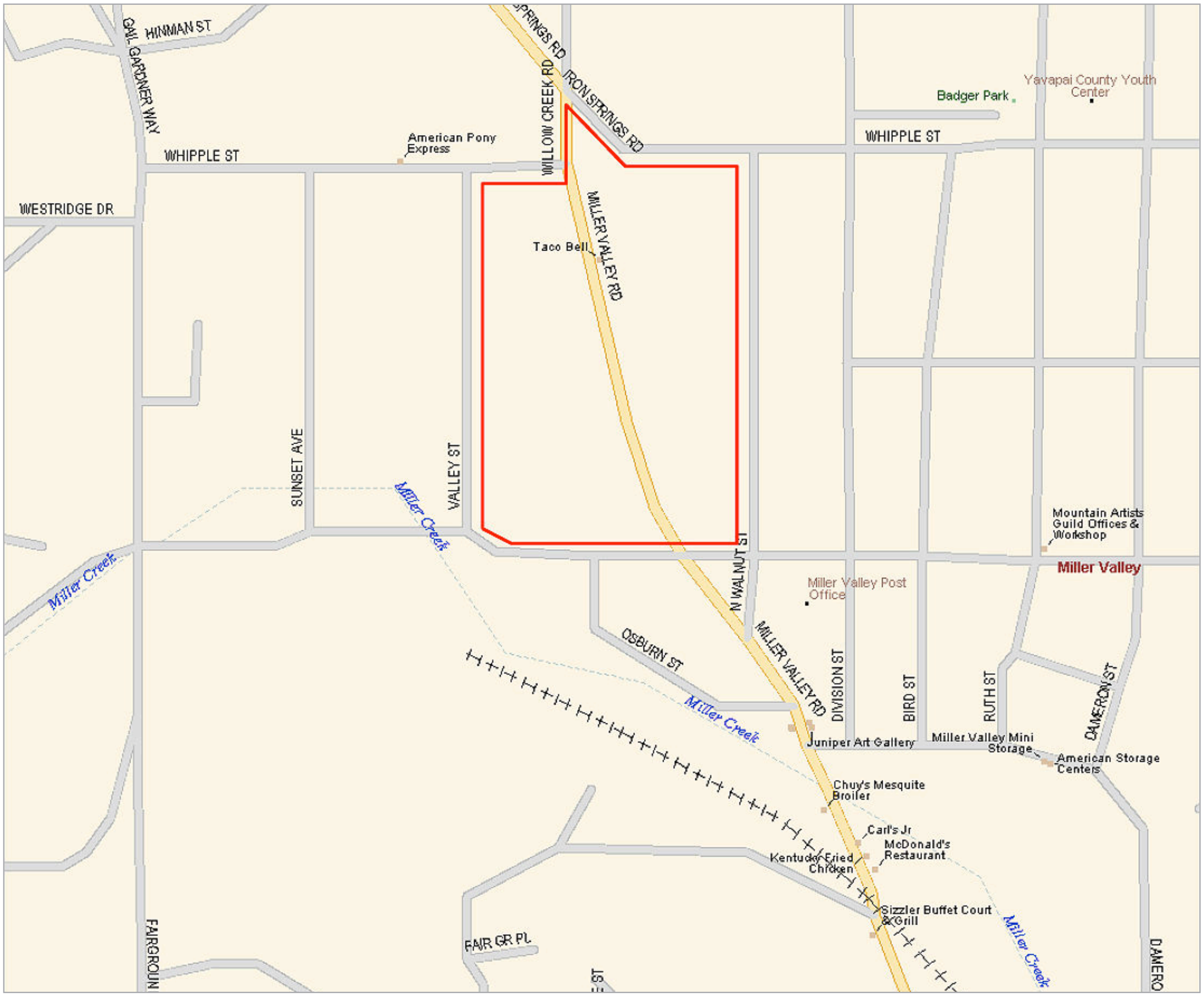
An environmental investigator and the Arizona Department of Environmental Quality (ADEQ) have successfully utilized passive soil gas (PSG) surveys in Arizona to cost-effectively investigate VOC impacts to groundwater and identify potential sources of impact. PSG surveys are minimally intrusive, and more 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). Perchloroethylene (PCE) was detected above the groundwater cleanup level of 5.0 micrograms per liter (ug/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 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.

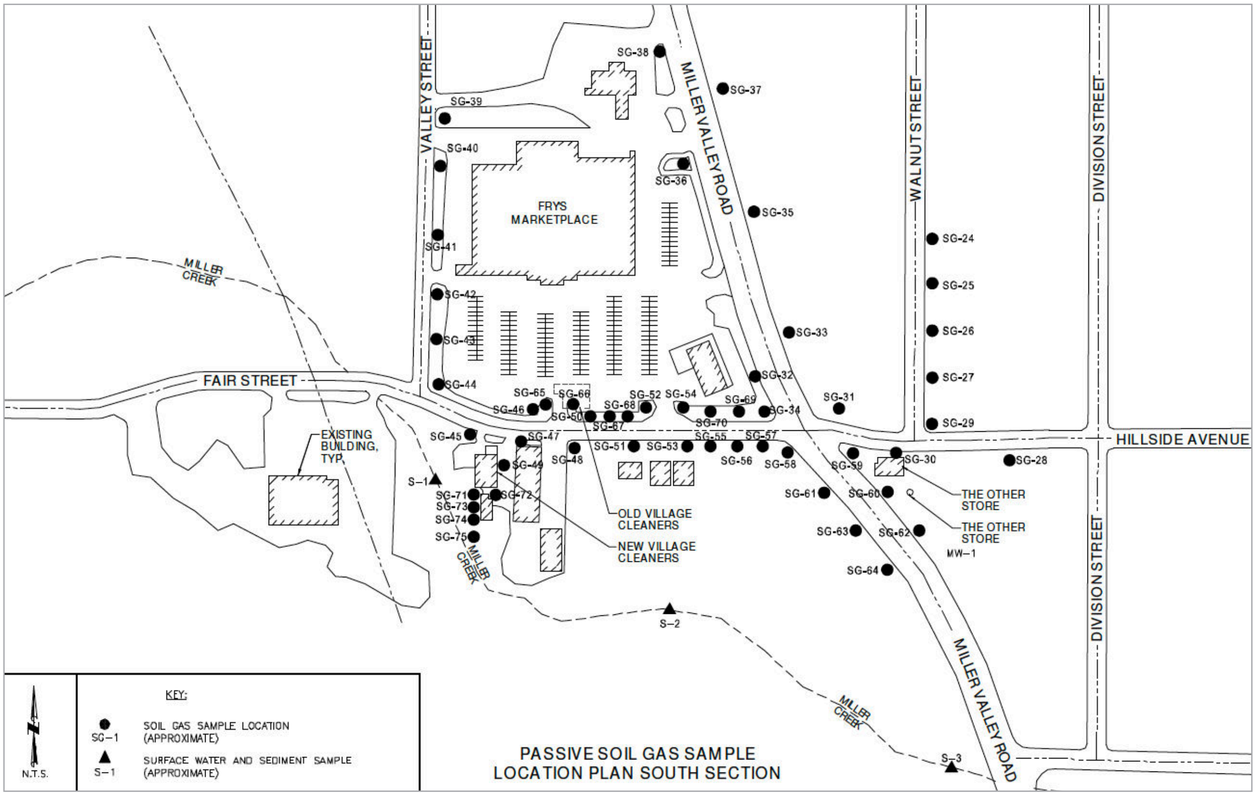
Exhibit 1 – Site Location



Hydrology

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 (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.

Exhibit 2 – Site Plan



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 below.

Passive Soil Gas Survey

A high resolution, passive soil gas 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 to collect samples and then submitted the samples to Beacon Environmental for analysis. Passive soil gas (PSG) surveys are ideal for measuring a wide range of volatile organic compounds (VOCs) in a broad range of materials in geologic formations. An advantage of PSG surveys is that the method allows for long exposure times which allow for the sorbents to be in contact with the organic gas or vapor to maximize the diffusive transport mechanism, as discussed in ASTM D 5314-92 (2006) and ASTM WK20609.

PSG surveys are a powerful and efficient tool if the appropriate quality controls are included in the technology design. This includes both the uniformity in the construction of the sampler as well as in the level of QA/QC used during the analysis of the samples. At a minimum, controls should be in place to ensure that (i) the appropriate hydrophobic adsorbents are used to target the compounds of concern, (ii) porous materials are not included in the sampler which may act as a competing adsorbent, (iii) an identical amount of adsorbent is used for each sampler, (iv) internal standards and surrogates are included with eachanalysis, and (v) that a multi-point calibration curve is performed with the low point of the curve below the method's reporting limit. The BESURE method adheres to each of these requirements.

The BESURE PSG sampler consists of a borosilicate glass vial pre-wrapped with wire for installation and retrieval of the sampler, shown in Exhibit 3. Each sampler contains two sets of adsorbent cartridges to adsorb compounds in soil gas. The adsorbent materials used are hydrophobic, with low affinity for water vapor that makes them effective even in water saturated conditions. An ample and identical amount of specialized adsorbents are contained within each cartridge to allow for a dynamic range of collection with reproducible results. In accordance with ASTM D 5314-92, no porous materials, such as PTFE, other than the adsorbent cartridges are used within the sampler, which can act as a competing adsorbent. The sampler is compact, allowing for installation in a variety of conditions and in small diameter holes.

BESURE samplers are most often installed in an approximately one-inch diameter hole that is between six-inches and three-feet in depth. Holes may be advanced to greater depths when necessary; however, the samplers need only be suspended in the upper portion of the hole because compounds in soil gas that enter the hole will migrate up to the sampler. Samplers typically are exposed in the field for 3 to 14 days, with the length of time dependent on the site conditions, the depth contaminants are expected to be present, the expected contaminant concentration, and the overall objectives of the survey.

One person can install up to 100 samplers per day with standard shallow installation when there is no asphalt or concrete present on the ground surface that would need to be drilled through. When asphalt and/or concrete is present, a two-person team can install on average 50 samplers per day using a hammer drill (with an approximately one-inch diameter drill bit). For retrieval of the samplers, one person can easily retrieve 100 samplers per day regardless of whether asphalt or concrete surfacing is present.

BESURE PSG samples are analyzed by Beacon Environmental using gas chromatography/mass spectrometry (GC/MS) instruments following EPA Method 8260B, modified for the introduction of samples by thermal desorption and to target a broad range of compounds including VOCs and SVOCs. PSG results are based on a higher level of QA/QC than can be achieved with other field screening methods and are based specifically on a five-point initial calibration with the lowest point on the calibration curve at or below the practical quantitation limit of each compound. Internal standards and surrogates are included with each analysis – per EPA Method 8260B – to provide proof of performance that the system was operating properly for each sample and to provide consistent reference points for each analysis, which enables an accurate comparison of measured quantities. Trip blanks are analyzed with each batch of samples and because two sets of adsorbent cartridges are provided in each sampler, duplicate or confirmatory analyses can be performed for any of the sample locations if requested.

Tabular results are provided in both hard copy and electronic copy along with color isopleth maps showing the distribution of selected compounds identified in the survey and targeted by the client. As an option, tentatively identified compounds (TICs) can be reported and complete data packages can be provided when necessary.

In the subject investigation, 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 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 samples were analyzed by Beacon Environmental for PCE, trichloroethylene (TCE), and cis-1,2-dichloroethylene (c-1,2-DCE) following EPA Method 8260B.

Exhibit 3 – BeSure PSG Sampler

Limited Confirmatory Groundwater Investigation

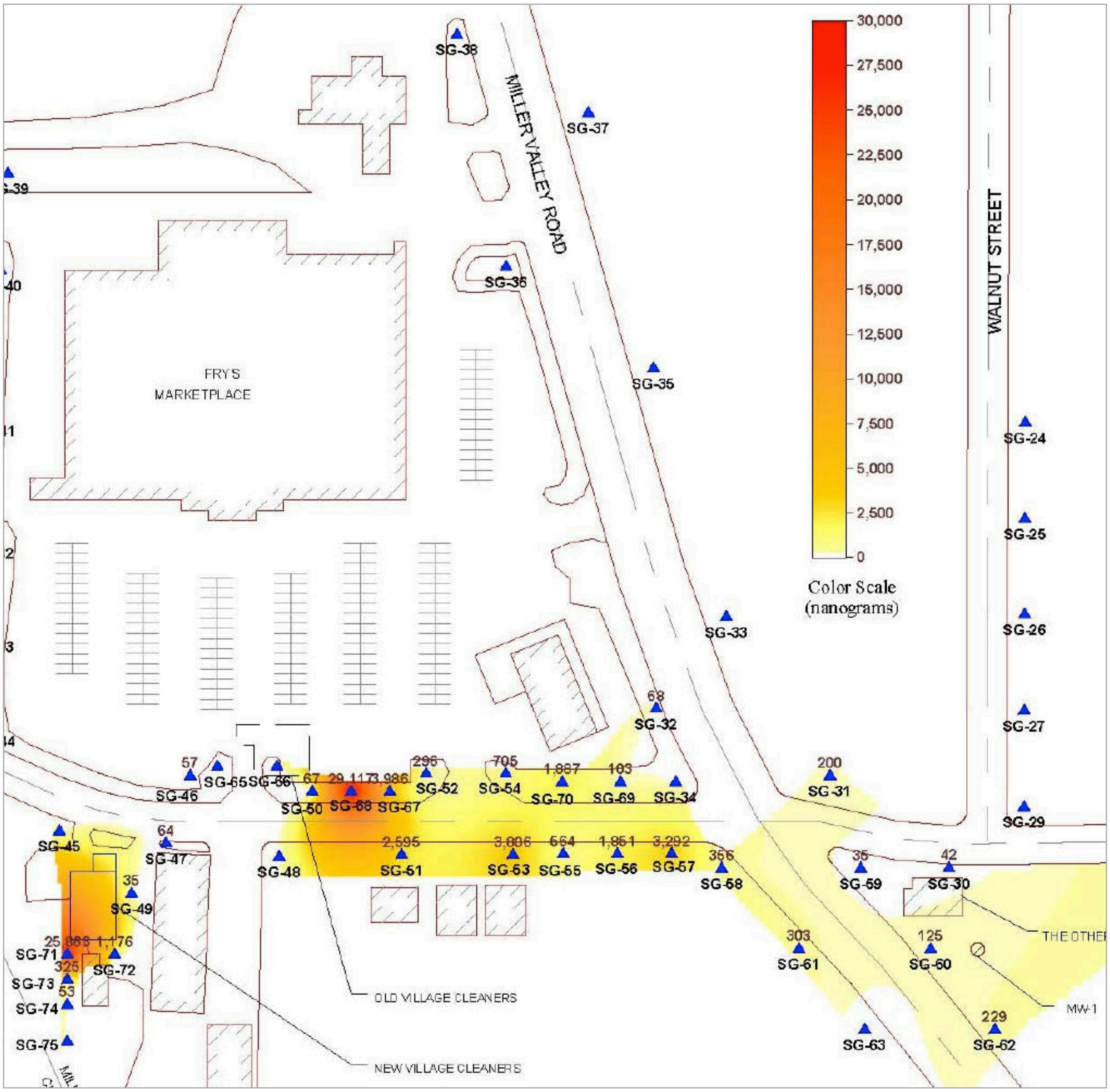
Based on the results of the passive soil gas survey, which are shown on Exhibit 4, a limited confirmatory groundwater investigation was performed. A total of 11 soil borings were advanced at the Site. The boring locations, which are shown on Exhibit 4, were based on the results of the passive soil gas 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 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)). 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 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. 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 EPA Method 8260B.

Results and Discussion

Passive Soil Gas Survey

The PCE results for the passive soil gas survey are shown on 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 non-detect (less than 25 nanograms (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 ug/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 ug/L of PCE. Potential sources of PCE impact to the groundwater were identified at samples SG-68 (29,117 ng PCE) and SG-71 (25,863 ng 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.

Exhibit 4 – Results of Passive Soil Gas Survey

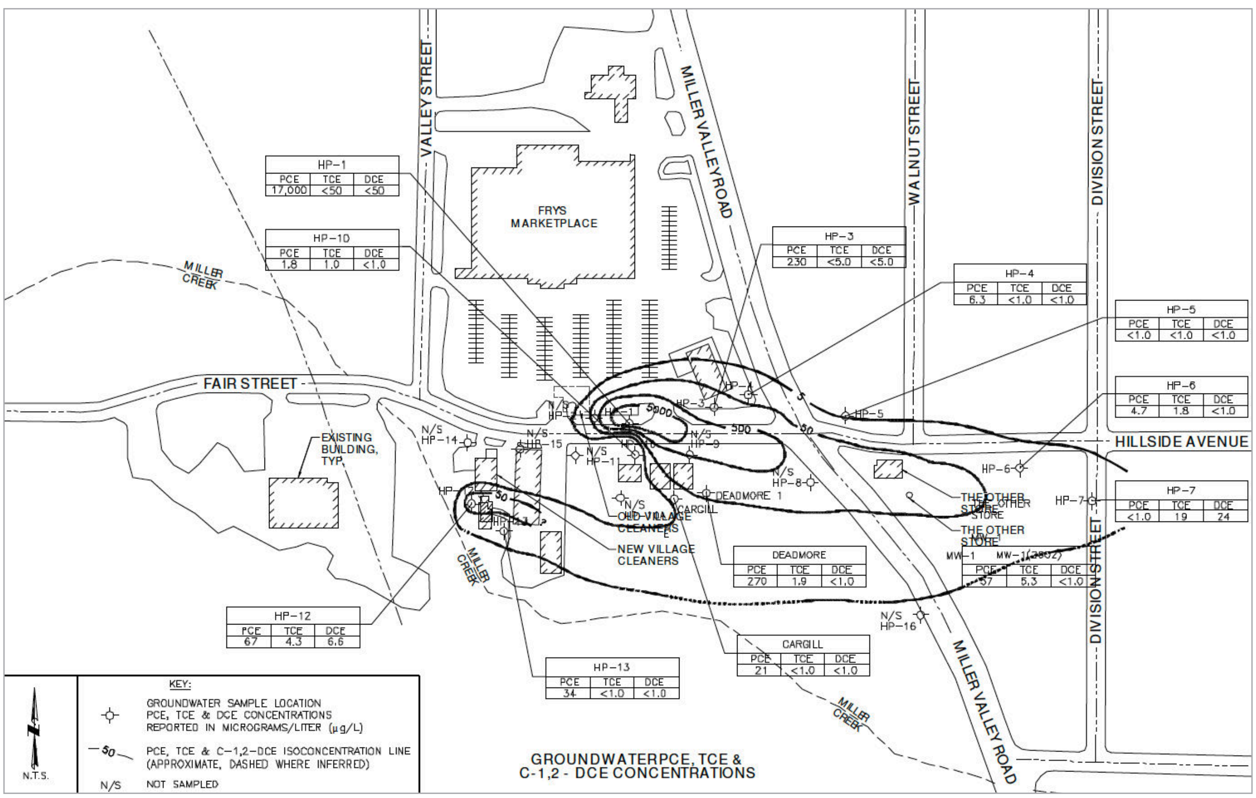


Limited Groundwater Investigation

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 on 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 ug/L and 67 ug/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 c-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.

Exhibit 5 – Groundwater Sample Locations and Results



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 used to collect grab groundwater samples was required to confirm the results of the passive soil gas 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 this 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 ug/L.

References

ASTM D 5314-92 (2006). Standard guide for soil gas monitoring in the vadose zone.

ASTM WK20609 (2008). Passive soil gas sampling in the vadose zone for source identification, spatial variability assessment, monitoring and vapor intrusion evaluations.

Biographical Sketches

James Clarke is a Principal Geologist in the Phoenix office of MACTEC Engineering and Consulting, Inc. Mr. Clarke has a MSE in Civil Engineering from Arizona State University and BS in Geology from Northern Arizona University. Mr. Clarke has 19 years of experience in site characterization, remedial investigations (RI), feasibility studies (FS), remedial/corrective action plans (RAP/CAP), risk-based closure, and remedial design. He has managed RIs under the Arizona Department of Environmental Quality (ADEQ) Water Quality Assurance Revolving Fund (WQARF) program and underground storage tank (UST) investigations and remediation projects regulated under the ADEQ leaking underground storage tank (LUST) program.

Deborah F. Goodwin has both a B.S. in Microbiology and a M.S. 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 and has managed soil gas investigations since 1991 for the DOD, DOE, and commercial markets. Mr. O'Neill continues to be on the forefront of passive and active sorbent technologies at the national and international level and has implemented the technologies at thousands of sites. Mr. O'Neill received his B.A. from Loyola College in Maryland.

Joseph E. Odencrantz, Ph.D., P.E. is Technical Director and Western Region Manager for Beacon Environmental 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 M.S. and Ph.D. in Civil and Environmental Engineering from The University of Illinois at Urbana-Champaign and his B.S. 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 Visiting Professor at the Research Center for Environmental Quality Management, Kyoto University from January through June, 2007.