pentachlorophenol. Operations included wood storage and pole peeling, and a treatment plant with pressure vessels, storage tanks, and drip racks.

The site is relatively flat with elevations ranging from 43.2 feet to 53.8 feet above mean sea level. The water table occurs at depths ranging from approximately 2 to 5 feet bgs. Surficial soils are part of the Beaumont Formation, which is composed of clays, silts, and silty sands. The depositional environment was fluvial and deltaic, and the deposits can be characterized as stream channel, point bar, mud flat, and coastal marsh. The majority of the soils are composed of continuous and noncontinuous clay to silty clay layers with two principal sand to silty-sand layers located at average depths of 15 feet and 30 feet bgs. The various clay layers are known to be fractured to various degrees. The site is intersected by at least three and possibly four relatively minor surface faults with displacements of 2 to 5 feet. At least one of these faults is known to be active.

The site was divided into separate soil and groundwater operable units during the feasibility study. The soil operable unit consists of approximately 10,000 cubic yards of contaminated soil that was excavated and stockpiled into a bioremediation cell. The groundwater operable unit was addressed through a pump-and-treat system consisting of 19 wells, pumps, a treatment plant, and three groundwater infiltration galleries. The pump-and-treat system operated at an average flow rate of 12 gallons per minute for 24 months. It removed approximately 7,000 gallons of DNAPL out of approximately 11,500,000 total gallons of extracted water. The pump-and-treat system was subsequently discontinued due to a drastic decline in the amount of DNAPL recovered.

Previous information sources of subsurface data consisted mainly of a limited number of boring logs and soil samples. In order to gather more information on the horizontal and vertical extent of DNAPL that exists in the subsurface and to refine the site conceptual model, the CPT/ROST™ technology was selected as the most cost effective option for data collection. A total of 101 pushes were completed at an average depth of approximately 45 feet for data collection. The data from the cone penetrometer portion of the tool, which is displayed similar to well logs, were used in the construction of isopach and structure maps and fence diagrams to aid in the characterization of the subsurface. Based on an extensive correlation of the pushes, it was determined that the tool's lithologic determinations were internally consistent and correlated well with the existing data. Also, due to the greatly increased number of data points, two and possibly three additional faults were located.

The ROST™ data, like that from the CPT portion of the tool, was provided in a format similar to a well log with total fluorescence graphed versus depth. Windows of the "waveform," which consisted of a graphical presentation of the breakdown of the total fluorescence into four wavelengths, were also presented on this log for various peak fluorescence values. This enabled a quick identification of the type of hydrocarbon contamination present at a given depth. Additionally, another log was provided which displayed the total fluorescence signature and a continuous breakdown of this signal into the four component wavelengths, which allowed more detailed analyses of the different types of hydrocarbons.

The data from the ROST™ portion of the tool was used to gain an understanding of the vertical and horizontal extent of creosote contamination, and the relative concentration of the creosote contamination in three dimensions. Due to the tool's ability to detect a wide range of hydrocarbon contamination, other sources of hydrocarbon, such as diesel, gasoline, and oil, were also discovered. Interestingly, four of the pushes, which are located adjacent to a known pipeline easement exhibit a relatively strong oil-like signature at shallow depths. It is postulated that this represents leaks in the pipeline. Because the focus of the investigation was creosote, these signals were filtered out from the total fluorescence signal by running the data through a FORTRAN program written specifically for that purpose. Refinement of this filtering methodology, although effective, is currently somewhat primitive and is undergoing further development.

When creosote was encountered, it was usually found at several depths within a given push. The tops of the creosote occurrences were tabulated by depth and by whether they occurred in a sand or a clay. It was determined that almost all of the creosote hits occurred within the two sands zones, with the lower sand zone registering the majority of the hits. The deepest creosote contamination that was observed occurred at a depth of approximately 50 feet bgs. Based on these data, the remediation strategy of the site has re-focused on the lower sand zone.

CPT/ROST™ has proven cost-effective for the determination of lithology and the delineation of creosote contamination at the North Cavalcade Superfund site. Also, based on its performance at the site, its effectiveness appears to extend to the identification of other less dense hydrocarbon signatures. The CPT/ROST™ offers advantages in both price and the rapidity with which the data can be acquired. This technology is being evaluated for use at two additional creosote sites.

Contact

Joe Kordzi, USEPA Region VI, 214-665-7186

4.2.2.2 X-Ray Fluorescence (XRF)

Tool Description

Energy dispersive XRF is used to analyze trace metals (e.g., mercury, chromium, lead, cadmium, copper, nickel, and arsenic) in soils, sludges, and groundwater. The technique uses x-rays (high-energy electromagnetic radiation) to penetrate the soil matrix and excite metals. Radiation emitted from fluorescence of the metals is measured to quantify the concentrations of metals present in the soil.

XRF analyzers yield semiquantitative results with detection from a few to a few hundred parts per million (ppm) depending on the soil matrix and the metals being analyzed. XRF is generally considered a screening tool because of its relatively high reporting limits. The XRF analyzer is easily transported to the field and very fast (reportedly 5 to 40 samples per hour can be analyzed depending on sample preparation and measurement times).

Operational Considerations
Several manufacturers supply XRF analyzers including TN Spectrace (the Spectrace 9000) and Metorex Inc. (the HAZ-MET 920, HAZ-MET 940, and the X-MET series). XRF analyzers contain a radioactive source that may require special handling. Although XRF methods do not require soil samples to be digested (as do conventional analytical methods), some sample preparation (e.g., drying and homogenization) may be required. XRF analyzers are susceptible to interference from water, petroleum, and soil heterogeneity. Nontechnical personnel may operate XRF analyzers with minimal training.

Applications and Cost
XRF methods are mostly used as screening tools for trace metals. Because of their relatively high detection limits, these methods are best suited to site characterizations requiring metal screening at relatively high levels.

The cost to rent an XRF analyzer is approximately $2,000/week. A comparative conventional analytical method (inductively coupled plasma) is 30 to 40 percent more expensive and requires that samples be digested.

Benefits
- No IDWs generated
- Easily transportable to the field
- Does not require digestion of soil samples

Limitations
- Sample preparation required (e.g., drying and homogenization)
- Poor detection limits on some metals, especially as a result of matrix interference
- Limited penetration depth
- Not well suited to measure liquid samples
- Radioactive source in the analyzer

Contacts
Jim Moore, TN Spectrace, (512) 388-9100, x208

James R. Pasmore, Metorex Inc., (541) 385-6748 or (800) 229-9209

4.2.2.3 Colorimetric Field Test Kits
Tool Description
Colorimetric field test kits are used to detect the presence or determine the concentrations of contaminants in soil and water. Because detection limits are generally in the low ppm range, field test kits are primarily used as a screening tool for site characterization. Colorimetric field test kits may be used to screen for a broad range of inorganic parameters, total hydrocarbons, selected organic compounds, and selected explosive compounds.

Colorimetry is generally performed by mixing reagents in specified amounts with the water or soil sample to be tested and observing the color change in the solution. The intensity of the color change is an indicator of the concentration of the chemical of interest. The color change is either observed visually (compared with color charts) or electronically with a handheld colorimeter.

It is important to understand the limitations of the specific test kit being used, including the chemicals it can detect. Some kits are susceptible to interference from both naturally occurring organic matter and other co-contaminants.

Specific vendor technologies discussed below include Handby, PetroFLAG™, PetroSense™, and Quick Testr field test kits. Handby field test kits are generally used to screen for petroleum-derived substances in soil and water. Results are quantified by comparison to substance-specific calibration photographs. Handby kits are also available to quantify PAHs. The PetroFLAG™ test kit for soil is primarily used to detect petroleum hydrocarbons with detection limits ranging from 20 to 2,000 ppm. The PetroFLAG™ test kit can use either a conservative calibration to estimate total hydrocarbons present or it can be calibrated to specific hydrocarbons. The Dexsil Corporation, which markets the PetroFLAG™ test kit, indicates that PAHs can be measured using the technology. The PetroSense™ PHA-100 Petroleum Hydrocarbon Analyzer (PetroSense™), marketed by FCI Environmental Inc., combines fiber optic chemical sensor technology and digital electronics to measure the vapor concentration of TPHs in soil and benzene, toluene, ethylbenzene, and xylenes (BTEX) in water. Envirol Inc., markets Quick Testr field test kits, which can estimate total cPAHs in soil. Quantitative results are obtained by establishing a site-specific correlation between test kit and laboratory results.

Operational Considerations

The Handby Kit is susceptible to positive interference if extremely large quantities of organic matter (e.g., peat) are present. The PetroFLAG™ is sensitive to a wide range of hydrocarbons including natural waxes and oils. For both the Handby Kit and PetroFLAG™, the user must test background samples and calibrate the equipment to detect only foreign (i.e., not naturally occurring) substances.

The Handby Kit analyzes a sample in less than 10 minutes; detection limits typically range from 1 to 1,000 ppm for soil and 0.1 to 20 ppm for water. Approximately 25 samples per hour can analyzed using the PetroFLAG™ field test kit. The PetroSense™ analyzer is very sensitive to turbidity and temperature in water samples. Preconditioning and calibration for the PetroSense™ take approximately 30 minutes; sample analysis takes less than 10 minutes. The PetroSense™ probe may be lowered directly into a borehole for analyzing in situ groundwater. The Quick Testr field test kit for cPAHs in soil reportedly takes less than 20 minutes per sample to analyze. The Quick Testr must be used in temperatures ranging from 40 to 110°F.

Applications and Cost

Test kits are most useful as screening tools. Colorimetric test kits are available for different media and contaminants. Prices vary with the type of kit. Most test kits include some of the following equipment: hand-held analyzer, glassware, reagents, and scales. The more expensive units use electronic colorimeters, and the less expensive units usually use visual colorimetric matches. Handby kits for soil or groundwater cost about $1,300 including enough reagent for 30 samples, and $550 for an additional 30 samples. The PetroFLAG™ kit for soil costs about $800 with enough reagent for 10 samples, and $250 for an additional 10 samples. The Petrosense™ rents for about $150/week plus minimal costs for calibration standards. The Quick Testr analyzer rents for about $275/week plus $40 per sample for consumables.

Benefits

- Rapid on-site screening tool
- Kits available for petroleum-derived substances and polynuclear aromatic hydrocarbon (PNAs)
- Useful for remote sampling
- Generally requires minimal training

Limitations

- Relatively high detection limits
- Possible interference by naturally occurring chemicals and other contaminants
- Possible difficulty reading colorimetric matches under low light conditions

Contacts

Dexsil Corporation (PetroFLAG™), (203) 288-3509, www.dexsil.com

Envirol, Inc. (Quick Testr), (801) 753-7946 or (435) 753-7946, www.environl.com

FCI Environmental Inc. (PetroSense™), (702) 361-7921

Handby Environmental Laboratory Procedures, Inc., (Handby Kit), (512) 847-1212

4.2.2.4 Immunoassay Screening

Tool Description

Immunoassay testing can be used in the field to detect target chemicals in soil and other samples. Most immunoassay-based test kits for analyzing environmental contaminants are of the competitive enzyme-linked immunosorbent assay (ELISA) type. In competitive ELISAs, the sample to be tested is combined with a labeled enzyme and an antibody to which both the contaminant in the sample and the enzyme will bind. The contaminant and the enzyme compete for the limited number of antibody binding sites that are available. Each will bind to a number of sites that is proportional to its concentration in the mixture, so the relative concentration of the contaminant can be determined.

The relative concentrations of enzymes and contaminants are indicated by color-producing reagents, which are added after the antibody with contaminants and enzymes bound to it is separated from whatever material is left over. Color development is catalyzed by the enzymes and then terminated by a stopping reagent. A spectrophotometer reads the absorbance or reflectance of the antibody-contaminant-enzyme complex; the color detected by the spectrophotometer is proportional to the enzyme's concentration and inversely proportional to the contaminant's concentration. Thus, the concentration of contaminant in the soil or other sample tested can be inferred.

Operational Considerations

Field immunoassay test kits can operate in temperature ranges from 40 to 100°F. Soil moisture content in excess of 30 percent can decrease extraction efficiency. Reactivity and / or interference from the surrounding soil matrix can have either a positive or negative effect on results. A work environment protected from sunlight and wind is recommended, and operator training by the manufacturer is encouraged.

To effectively use immunoassay test kits for field screening at MGP sites, a site-specific correlation study should be performed first. PAH immunoassay test methods measure PAH compounds based on molecular structure. Laboratories use gas chromotography / mass spectrometry (GC / MS) for ion identification to quantify 16 different PAHs. The presence of any of the more than 30 PAHs can be detected, but without identifying specific types or quantifying concentrations.

Immunoassay test kits should not be used at MGP sites where crude oil was used as a fuel source because the widely varied composition of feedstocks for oil-fired plants does not allow correlation to a standard based on simple feedstock. MGP sites where coal was used as a fuel source yield much better correlation factors between analytical laboratory data and immunoassay test kit data in field tests.

Applications and Cost

Immunoassay test kits may be an effective screening tool for PAHs, TPHs, and other chemicals typically detected at coal-fueled MGP sites. Immunoassay test kit cost per sample is $25-55 (excluding labor) depending on batch size and product line. Field lab instrumentation can be rented for $450 / week or purchased for $1,700-2,000.

Benefits

- Rapid, real-time analytical data on-site
- Can be used to select samples for laboratory analysis and to define limits of contamination during an investigation

Limitations

- Requires site-specific calibration

- Does not speciate individual PAHs
- Does not work effectively on MGP sites where crude oil was used as fuel
- Does not produce quantified concentrations of target substance being analyzed
- Requires a trial period or test runs to confirm satisfactory performance

Contact

Dwight Denham, Strategic Diagnostics, Inc., (714) 644-8650

Case Study

Georgetown Former MGP Site

In 1930, the Georgetown Coal Gas plant was demolished after about 20 years of operation. The objectives of using immunoassay kits at the Georgetown Former MGP Site were to evaluate the entire site quickly and to find areas with actionable levels of PAHs, determine the extent and depth of each contaminated area, and compare in-laboratory methods with immunoassay results in terms of accuracy, cost, and time. Of the 36 samples analyzed at the site, the PAH immunoassay test kits were consistent with in-laboratory results with the exception of five false positives from the immunoassay test method. By not performing laboratory analysis of the samples determined to be negative via immunoassay (as defined by a concentration less than 1 ppm), a savings of approximately $4,000 would have been realized. Used as a screening tool, the immunoassay results can be very useful in determining which samples to send to a lab (immunoassay costs were approximately one tenth of laboratory analysis).

4.2.2.5 Mobile Laboratories

Tool Description

Under the right conditions for field programs in which rapid site assessment is necessary, mobile laboratories can provide rapid on-site, soil, air, and water sample analyses.

Field characterization programs are often conducted in phases of field sample collection and analysis. The results from the first phase are used to plan the sampling strategy of the second phase. The results from the second phase are used to plan sampling for a third phase, and so on until delineation of contaminants is complete. The time spent between phases waiting for analytical results from standard offsite laboratories translates into additional costs for repeated mobilization / demobilization of drilling equipment and field personnel. Mobile laboratories can provide same-day results for field sampling, allowing field personnel to make quick decisions about the locations of subsequent sampling. It is not necessary to demobilize then remobilize the sampling effort.

Operational Considerations

The analytical capabilities of mobile laboratories vary considerably among companies. However, several laboratories are equipped to analyze PAHs in addition to petroleum hydrocarbons and other common contaminants. Some mobile laboratories are also equipped to analyze natural attenuation parameters in the field. Many natural attenuation parameters (e.g., dissolved oxygen, oxidation-reduction potential, ferrous iron, hydrogen, methane, ethane, and ethene) require rapid analysis for accurate reporting, so mobile laboratories can be very effective for analyzing these parameters.

Several mobile laboratories can identify and quantify PAHs by SW846 Methods 8100, 8270, and 8310. Prior to selecting a mobile laboratory, it is important to determine the quality of data required (e.g., are results from immunoassay methods acceptable, or are gas chromatography / mass spectrometry procedures warranted). Similar to offsite laboratories, mobile laboratories require trained chemists to run analyses and perform QA / QC functions.

Applications and Cost

The decision to use a mobile rather than an offsite laboratory depends on a number of factors, including quality of data required, number of samples to be analyzed, types of analyses required, possibility of access to a fixed laboratory, and cost of onsite versus offsite analysis.

If the mobile laboratory does not require specialized instrumentation, the cost of sample analysis may be 10 to 15 percent less than the cost of sending samples offsite and requesting rapid turnaround (Onsite Laboratories, 1998). It is important to note that the cost of laboratory analyses at both onsite and offsite situations varies markedly among laboratories and that unit costs depend on the number of samples to be analyzed. Approximate laboratory rental costs are $2,500 to $3,000 plus $13 to $30 per sample for expenditures.

Benefits

- Extremely rapid turnaround analytical results
- May reduce mobilization / demobilization charges for drilling and field personnel
- Can rapidly perform time-critical analyses, such as for natural attenuation parameters

Limitations

- May be more efficient to send samples for rapid turnaround at an offsite laboratory
- More expensive than standard turnaround analysis
- Not all mobile laboratories use USEPA analytical methods

4.2.3 Geophysical Surveys

Geophysical surveys encompass a broad group of tools historically used by the geophysical, mining, and petroleum industries for mapping geological formations. All of these tools operate from the surface to sense buried obstructions and objects, changes in geologic formations, and / or the location of groundwater, thus minimizing uncertainty about what might be unearthed during excavations and giving additional information to conceptual and numerical modeling of groundwater flow. These tools are generally grouped into one of two categories: surface geophysical and borehole geophysical.

Surface geophysical tools are nonintrusive and include:

- Electromagnetics
- Seismic Refraction
- Ground-Penetrating Radar
- Magnetometry / Metal Detection

Borehole geophysical tools are designed to be put into a well or borehole. They include:

- Electrical Logging (including single-point and multi-electrodes)
- Mechanical Logging
- Sonic Logging
- Radiometric Logging
- Thermal Logging
- Video Logging

In general, all geophysical tools work on a “preponderance of evidence” basis. That is, an individual geophysical method does not typically provide definite results. Rather, several methods are used in conjunction at a site to provide information concurrently through their results.

4.2.3.1 Electromagnetics

Tool Description

Electromagnetic surveys (EMS) comprise two subclasses of surveys: magnetometer surveys and terrain conductivity electromagnetic surveys. Both types of surveys are nonintrusive geophysical surveying techniques that have traditionally been used to detect geologic features (e.g., formations with magnetic properties). More recently, EMS has been successfully applied with ground-penetrating radar (GPR) surveys at former MGP sites to locate buried obstructions and objects such as old underground storage tanks, buried sumps and pits, and current and abandoned utility lines.

Magnetometer surveys are conducted by using an instrument that measures the varying intensity of magnetic fields produced by natural objects (e.g., rocks) and man-made objects (e.g., utility lines). Interpreting the magnetic readings produced by the magnetometer allows conclusions to be drawn about the location of the buried objects.

Terrain conductivity electromagnetic surveys are conducted by remote seismic inductive electric measurements made at the surface. The apparent conductivity of subsurface formations and objects is measured by a conductivity meter consisting of a receiver coil and a separate transmitter coil that induces an electric source field in the ground. Lateral variations in conductivity values generally indicate a change in subsurface conditions. The figure below is an example of an output from a terrain conductivity electromagnetic survey.

Operational Considerations

Soil factors that affect the accuracy of EMS include moisture content, iron content, and dissolved salts and ions. EMS results can also be affected by electromagnetic interference. Overall, EMS results are best interpreted in parallel with other geophysical survey techniques, such as ground-penetrating radar surveys, that provide correlating information.

Applications and Cost

EMS uses a nonintrusive source and detectors and is therefore ideal for screening sites for buried objects. It is a fast, relatively inexpensive method to obtain “ballpark” data. Under favorable conditions (low moisture, low iron content, low electromagnetic interference), EMS’s resolution and accuracy improve. EMS is well understood and provides reliable results.

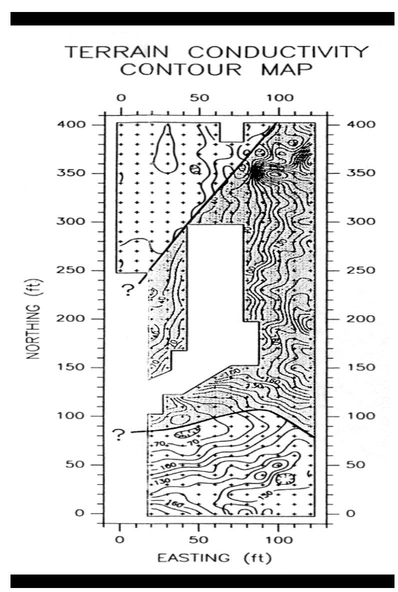
The cost of an EMS survey varies depending upon access to the site (directly related to the time required to perform the field work) and detail desired (e.g., the target depth to which a survey is to be conducted). Typically, an EMS survey on a 1-acre site will take 3 to 4 days to complete, costing around $3,500.

Benefits

- Provides reliable data
- Field tested and proven

Limitations

- Requires expertise to plan, collect, and interpret data
- Data subject to interference from soil moisture or clay in the subsurface and nearby electromagnetic sources (e.g., power lines)
- May be problematic in iron-rich, deeply weathered soils



Case Studies

Chico Former MGP Site

Available historical information for PG&E’s Chico former MGP site indicated multiple locations for the historical buried feedstock tank. Terrain conductivity electromagnetic surveys were performed in conjunction with GPR to determine whether the tank still existed and, if so, to better estimate the tank’s location (thereby determining if soil contamination observed in the general area might be from the tank or from a different former MGP structure). At the time of the surveys, the site consisted of the former MGP sheet-metal generating building and an adjacent substation. There was significant interference in the EMS survey from the adjacent substation, but the GPR survey was able to place the location of the former buried feedstock tank farther west than the location estimated from historical Sanborn Fire Insurance maps.

Stockton Former MGP Site

Terrain conductivity electromagnetic surveys were also used at PG&E's Stockton former MGP site to delineate debris-filled areas, covered pits and sumps, and concealed foundations associated with the former MGP. The terrain conductivity electromagnetic surveys correlated well with the estimated locations of former MGP structures as determined by a GPR survey.

Contact

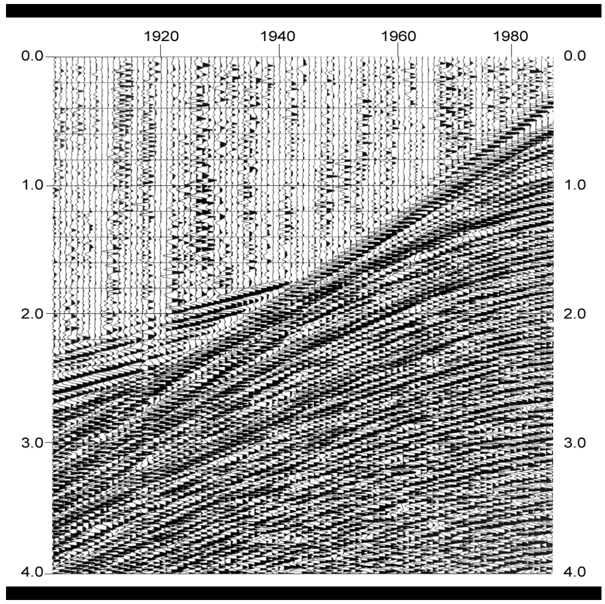
Robert Doss, Pacific Gas and Electric Company, (415) 973-7601

4.2.3.2 Seismic Refraction

Tool Description

Seismic refraction is a nonintrusive geophysical surveying technique that can be used to determine depth to bedrock, thickness of surficial fracture zones in crystalline rock, extent of potential aquifers, and depth of the water table.

Seismic refraction surveys are conducted by measuring the velocity of elastic waves in the subsurface. Elastic waves are generated by a source (hammer blow or small explosion) at the ground surface, and a set of receivers is placed in a line radiating outward from the energy source to measure the time between the shock and the arrival. The velocity of the elastic waves in the subsurface increases with increasing bulk density and water content. The depth of various strata and objects may be calculated if their wave velocities are sufficiently different. The survey data are processed and interpreted, typically along with other geologic information and geophysical surveys, to provide a picture of subsurface conditions. The following figure exemplifies the output from a seismic refraction survey.



Three-dimensional / three-component (3-D / 3-C) seismic imaging can be an extremely powerful tool for characterizing the hydrogeological framework in which contaminants are found at MGP sites. 3-D / 3-C seismic imaging is a nonintrusive geophysical surveying technique that can delineate subsurface geophysical features including: bedrock channels, clay layers, faults, fractures, and porosity. In addition, 3-D / 3-C seismic imaging can identify trench / pit boundaries and differences in soils and wastes (Hasbrouck et al., 1996).

3-C imaging entails analysis of one-component compression-wave and two-component shear-wave data. Two-dimensional (2-D) seismic refraction surveys use only one–component compression-wave data. The 3-D / 3-C seismic imaging uses shear-wave data to map much thinner features than can be detected with 2-D surveys; 3-D / 3-C imaging can determine anisotropy (i.e., preferred grain orientation, periodic layering, and depositional or erosional lineation), which may correlate to preferential contaminant transport pathways (Hasbrouck et al., 1996).

Operational Considerations

Interpretations of seismic refraction surveys are most reliable in cases where there is a simple two- or three-layer subsurface in which the layers exhibit a strong contrast in seismic velocity. For shallow investigations (i.e., up to approximately 10 feet deep), the energy source for the elastic waves is a hammer blow on a metal plate set on the ground surface. For a deeper investigation or at sites with noise interference (heavy machinery or highways), an explosive source is necessary. High gravel content in the soil matrix may diminish the quality of the data.

3-D / 3-C seismic imaging data can be processed so that cross sections are oriented from any angle and specific zones of interest can be displayed and interpreted. Specially developed 3-D / 3-C software is necessary to process the data, and skilled data interpretation is required (Hasbrouck et al., 1996).

Overall, seismic refraction results are best interpreted in parallel with other geophysical survey techniques (such as magnetometer surveys and electromagnetic terrain surveys) or well logs, which provide correlating information.

Applications and Cost

Where deep groundwater, consolidated materials, or both make test drilling relatively expensive, it may be advantageous to get as much information as possible by seismic refraction. Seismic refraction is a nonintrusive survey method that is well understood and provides reliable results.

3-D/3-C seismic imaging can be used for subsurface characterization. The relatively high cost of 3-D/3-C seismic imaging may be justified in situations where site entry is restricted because of high levels of subsurface contaminants and a three-dimensional picture of the sites's subsurface is required without intrusive sampling.

The cost of a seismic refraction survey varies depending upon access to the site (directly related to the time required to perform the field work) and the level of detail desired (e.g., the target depth to which the survey is to be conducted). Typically, one week of seismic refraction surveys may yield 3 to 5 line miles of interpreted data for approximately $10,000.

Benefits

- Provides reliable data
- Field tested and proven
- Minimizes the number of times an area must be accessed for subsurface characterization and maximizes the amount of information gathered
- 3D/3C seismic refraction provides greater level of detail (e.g., thinner features) than traditional 2-D seismic surveying results

Limitations

- Requires expertise to plan, collect and interpret data
- Data subject to interference from complex geological strata
- 3D-3C seismic refraction relatively expensive
- Needs to be correlated with other site-specific subsurface data such as drilling logs
- Heavy traffic or numerous surface obstructions can be problematic

Contact

Dennis Olona, U.S. Department of Energy, Albuquerque, NM, (505) 845-4296

4.2.3.3 Ground-Penetrating Radar (GPR)

Tool Description

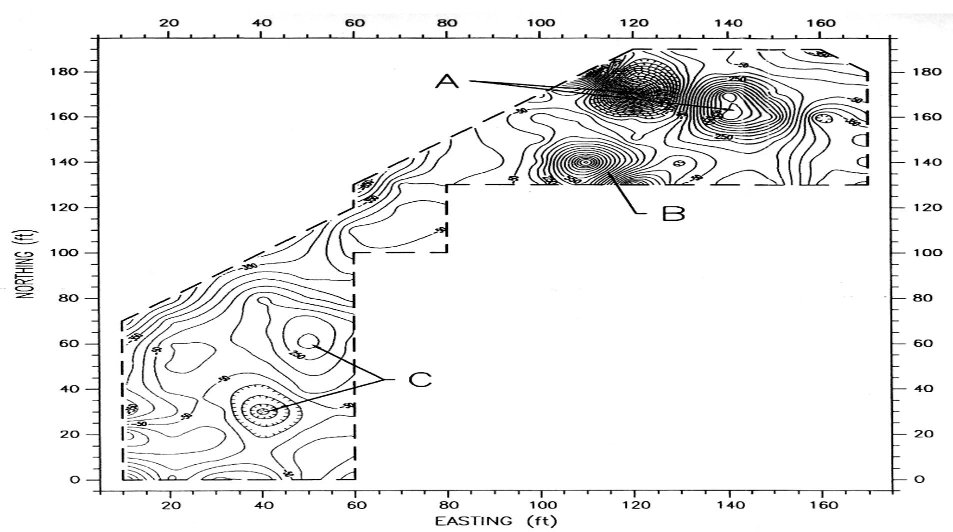
GPR is a nonintrusive geophysical surveying technique that has traditionally been used to detect geologic features (e.g., fractures and faults). More recently, GPR has been successfully applied with EMSs at former MGP sites to locate buried obstructions and objects such as old foundations, underground storage tanks, buried sumps and pits, current and abandoned utility lines, and concrete rubble.

GPR surveying emits high-frequency electromagnetic waves into the subsurface. The electromagnetic energy that is reflected by buried obstructions is received by an antenna at the surface and recorded as a function of time. The recorded patterns are interpreted, typically along with other geologic information and geophysical surveys, to provide a picture of subsurface conditions. The following figure is an example of an output from a GPR. Results are best interpreted in parallel with other geophysical survey techniques, such as magnetometer surveys and EMSs, which provide correlating information.

Applications and Cost

GPR uses a nonintrusive source and detectors and is therefore ideal for screening sites for buried objects. It is a fast, relatively inexpensive method to obtain “ballpark” data. Under favorable conditions (low moisture, low iron content, low electromagnetic interference), GPR’s resolution and accuracy is best. GPR is well understood and provides reliable results.

The cost of a GPR survey varies depending upon access to the site (directly related to the time required to perform the field work) and the level of detail desired (e.g., the target depth to which the survey is to be conducted). Typically, one week of GPR surveys yields 5 to 7 line miles of interpreted data for around $10,000.



Benefits

- Field tested and proven

Limitations

- Requires expertise to plan, collect, and interpret data
- Data subject to interference from soil moisture or clay in the subsurface
- May be problematic in iron-rich, deeply weathered soils

Case Study

Chico Former MGP Site

Historical information for PG&E's Chico former MGP site indicated multiple locations for the buried former feedstock tank. Ground-penetrating radar was used in conjunction with EMS to determine whether the tank still existed and to verify its location (in order to determine whether soil contamination observed in an area might be from the tank or from a different former MGP structure). Although there was significant interference in the EMS survey from an adjacent substation, the GPR survey placed the location of the former buried feedstock tank farther west than the location estimated from historical Sanborn Fire Insurance maps. Interpretation of the survey data identified the location of the tank excavation but was not able to confirm whether or not the tank was still in place.

Contact

Robert Doss, Pacific Gas and Electric Company, (415) 973-7601

4.2.3.4 Magnetometry/Metal Detection

Tool Description

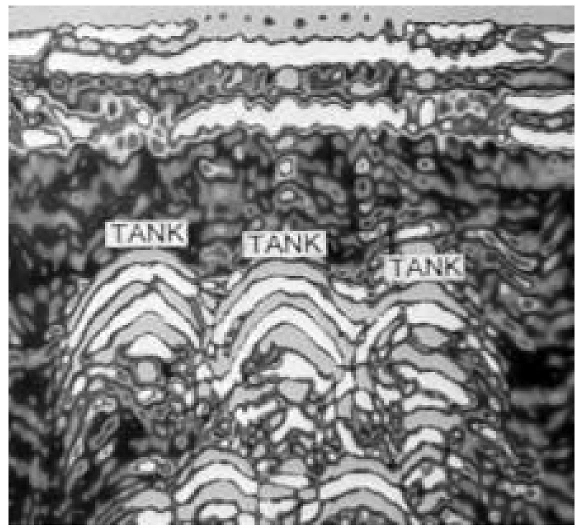
Magnetometry is a nonintrusive electromagnetic geophysical surveying technique commonly used in the construction industry to detect and map buried drums, metallic pipes, utilities, cables, and piping before excavation, demolition and/or construction. This technology has also been applied to former MGP sites to identify buried utilities before drilling and to survey and map historical MGP structures such as buried piping, tanks, and other metal structures.

Magnetometer surveys use an instrument that measures the varying intensity of magnetic fields produced by buried metallic objects. The magnetic readings produced by the magnetometer can be interpreted so that conclusions can be drawn about the location of the buried objects. The following figure is an example output from a magnetometer survey.

Operational Considerations

Soil factors that affect the accuracy of magnetometry include moisture content, iron content, and dissolved salts and ions. In addition, magnetometry surveys are typically depth limited and cannot distinguish among types of metallic objects. Nonferrous objects are invisible to magnetometry survey instruments.

Applications and Cost



Magnetometry uses a nonintrusive source and detectors and is therefore ideal for screening sites for buried objects. It is a fast, inexpensive method to obtain “ballpark” data on the location of buried metallic objects. Under favorable conditions (low moisture, low iron content, low electromagnetic interference), magnetometry resolution and accuracy is best. Magnetometry is well understood, well accepted, and provides reliable results.

The cost of a magnetometry survey varies depending upon access to the site (directly related to the time required to perform the field work), the size of the area to be surveyed, and the level of detail desired (e.g., the target depth to which the survey is to be conducted). Typically, a magnetometry survey on a 1-acre site with 10-foot grid spacing will take 3 to 4 days to complete. Equipment rental may cost approximately $500 per month, exclusive of labor (for both testing and data interpretation) and other related expenses.

Benefits

- Field tested and proven
- Widely accepted

Limitations

- Details obtainable only at relatively shallow depths
- Cannot distinguish among metallic objects
- May be problematic in iron-rich, deeply weathered soils or where there is a lot of scattered metal debris
- Nonferrous objects will not be visible to the technology

4.2.3.5 Borehole Geophysical Methods

Borehole geophysical methods are used to physically characterize sediments, rocks, and fluids in boreholes and wells. Data are acquired by moving a string of instruments up or down a borehole and measuring the response. Depending on the specific information required, one or more borehole geophysics techniques may be used in a single well. The radius of the investigation depends on the particular instrument used.

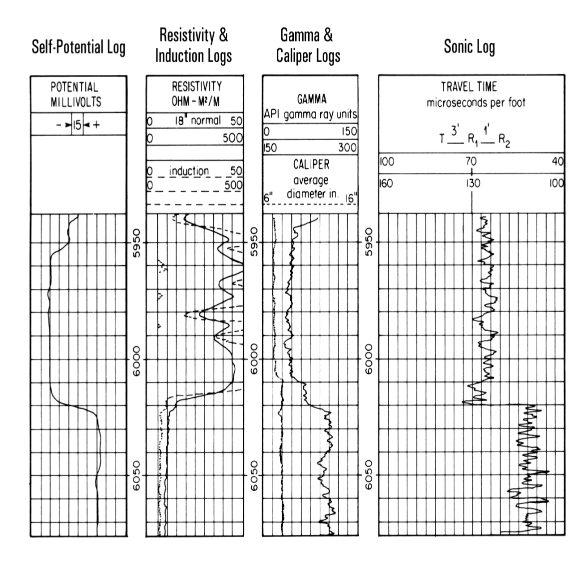
The tools discussed below include several categories of borehole survey techniques:

- Electrical
- Mechanical
- Sonic
- Radiometric
- Thermal
- Video

Borehole geophysical logging is a useful tool for site characterization. Because of the mobilization effort required and because multiple logging techniques can be used simultaneously, borehole geophysical surveys are most cost effective when performed as part of a multiple-log suite.

Geophysical logs provide a continuous profile of response versus depth in a well or boring. Typically, direct soil sampling is undertaken only at 5-foot intervals. A substantial amount of information can be obtained from a few logging runs into a well. In addition, data can be correlated between adjacent wells. Examples of some of the well logs that may be produced with the techniques discussed herein is shown below.

In general, borehole logging is relatively expensive (including actual logging and post processing), and equipment must be transported to the site. In addition, the radius of the investigation may be small and may not be representative of the bulk formation.



4.2.3.5.1 Electrical Logging

Tool Description

Electrical logging includes electrical resistivity methods, induction logs, self-potential logs, and fluid conductivity logs. Electrical resistivity relies on different electrode configurations to give information on different zones around the borehole. The characteristics (e.g., thickness, permeability, salinity) of a region energized by particular current electrode configuration can be estimated by measuring variations in current among electrodes. Many variations of electrical resistivity logging exist in which different electrode configurations are used including: normal logs, lateral logs, guard logs, and micrologs. Using empirical constants specific to the particular rocks in the area and the drilling fluid, electrical resistivity is also used to estimate porosity, water and hydrocarbon saturation, and permeability.

An induction log is a profile of resistivity obtained by utilizing electromagnetic waves. This technique is used in dry holes or boreholes that contain nonconductive drilling fluid. Lithologic boundaries show up on induction logs as gradual changes in apparent resistivity.

On self-potential logs, measurements of potential differences between an electrode on the sonde (probe) and a grounded electrode at the surface are made in boreholes filled with conductive drilling fluid. The self-potential effect originates from the movement of ions at different speeds between two fluids of differing concentration, in this case groundwater and drilling fluid. Self-potential logging can be used to identify the boundaries between geological beds based on the differing rates of penetration of drilling mud into the lithology. In hydrocarbon-bearing zones, self-potential logs show less deflection than normal.

Fluid conductivity logging uses an electrical conductivity probe to profile water quality by depth. It is used to select sampling depths and also used in conjunction with a flow-meter log (see Section 4.2.3.5.2, Mechanical Logging) to identify water-producing zones.

Operational Considerations

The electrical logging techniques described here require an open borehole. Borehole fluids must be electrically conducting if electrical resistivity and self-potential logging are to be used. Induction logging, however, requires either a dry borehole or nonconducting fluids in the borehole. Single-electrode logging yields a poor response in saltwater aquifers and provides qualitative data elsewhere. Multi-electrode logging permits quantitative data and estimates of formation water salinity. Fluid conductivity logging yields less precise information in highly saline waters.

Applications and Costs

The cost of electrical logging is approximately $1,200-$2,500 per day. Five to seven wells can be logged per day. Fluid conductivity logging is approximately $500-$600 per well when performed as part of a multiple-log suite and approximately $1,500-$2,500 per well when done alone.

Benefits

- Quantitative data may require corrections

Limitations

- The electrical logging techniques described require an uncased borehole
- Electrical resistivity and self-potential techniques require conductive borehole fluids
- Induction logging requires a dry borehole or borehole with nonconductive fluids
- Induction logging may be complex and provide poor results in situations of high-resistance formations, thin beds, and shallow wells
- Poor response in saltwater aquifers

4.2.3.5.2 Mechanical Logging

Tool Description

Flow-meter and caliper logging are two different types of mechanical logging. Flow-meter or spinner logging incorporates mechanical flow meters to measure horizontal and vertical groundwater flow rates. These flow rates can be used to identify permeable zones in a formation. When used in conjunction with the caliper log, the flow meter yields semiquantitative measurements of groundwater into the borehole.

A mechanical flow meter measures the velocity of fluid in a borehole by means of low-inertia impellers that are turned by the fluid flow. Turning of the impellers causes a magnet mounted on the impeller shaft to rotate and generate electrical signals. Mechanical flow meters are capable of measuring flow rates down to about 2 feet per minute (ft/min). A newer electromagnetic flow meter uses thermal principles to measure flow rates as low as 0.1 ft/min.

Mechanical flow-meter logging can be done under natural (non-pumping) or forced-flow (pumping) conditions. Pumping flow-meter logs can be used to estimate the relative transmissivity of different water-bearing zones; non-pumping flow-meter logs can be used to identify the direction and magnitude of vertical well-bore flow caused by vertical gradients.

Another common type of mechanical logging uses the caliper log, which measures borehole diameter and roughness. The tool itself has a number of feelers (usually four) attached. The feelers are electromechanical devices, held by springs against the wall of the hole, that send information to the surface. The information from the log is used mainly to estimate the volume of cement that might be required to seal around a collapsed region, to verify well-construction details, and to provide lithologic information. Information gained from the caliper log is used to estimate velocity losses in the gap between the borehole wall and the flow-meter impeller, thereby correcting velocity measured by the flow-meter log. The key use of the caliper log data is to correlate vertical velocity data to vertical flow data by allowing the area of the borehole to be factored into the vertical profile.

Operational Considerations

Flow-meter logging requires a minimum flow of approximately 2 ft/min. Caliper logging requires an open borehole, which may be difficult to achieve in deep, unconsolidated deposits. Conductor casing may be necessary to contain unconsolidated sediments near the top of the well.

Applications and Costs

The cost of flow-meter logging is roughly $500 to $600 per well when performed as part of a multiple-log suite. The cost of flow-meter logging (with recommended caliper logging) is $1,500 to $2,500 per well.

Benefits

- Caliper log is widely available, rapid, and inexpensive
- Flow meter logging is relatively simple and inexpensive

Limitations

- Flow-meter logging is relatively insensitive at low velocities
- Most applications of flow-meter logging require a pumping or flowing well during the survey
- A caliper log is needed for interpretation of flow-meter logs

4.2.3.5.3 Sonic Logging

Tool Description

Sonic logging, also known as continuous velocity or acoustic logging, is used to determine the relative porosity of different formations. Sonic logging may also be used to determine the top of the water table, to locate perched water-bearing zones, and to assess the seal between a casing and formation material.

A probe containing one or more transmitters that convert electrical energy to acoustic energy is lowered into the borehole on a cable. The acoustic energy travels through the formation and back to one or more receivers also located on the tool. The acoustic energy is converted back to an electrical signal, which is transmitted back to the surface by the receivers and recorded.

Sonic logging determines the seismic velocities of the formations traversed. The average velocity of the acoustic wave passing through the formation depends on the matrix material and the presence of fluid in the pore space. The speed of the wave is slowed by the presence of pore fluid; therefore, sonic logging provides a measure of fluid-filled pore space. The velocity of the solid matrix can be determined by laboratory analysis of core samples.

Operational Considerations

Sonic logging can be performed in a borehole cased with metal; however, the results are most representative of formation properties if logging is performed in an open borehole. The borehole must be fluid-filled for signal transmission to occur. Obtaining meaningful results in unconsolidated materials with low groundwater velocities may be difficult.

Applications and Costs

Sonic logging may be used for site characterization where information is needed on the relative porosity of different formations and the location of water-bearing zones. The cost of sonic logging is approximately $1,500 to $4,500 per well.

Benefits

- Widely available
- Suitable for uncased or cased boreholes although the results are more representative of the formation if the borehole is uncased
- Useful for characterizing rock aquifers to identify high-porosity zones that may transmit water
- Allows porosity determination without use of radioactive source

Limitations

- Interpretation of the data may require expertise
- The borehole must be fluid-filled
- Not applicable in shallow wells or in unsaturated conditions

4.2.3.5.4 Radiometric Logging

Tool Description

The radiometric logging techniques discussed here include neutron logging and natural gamma (or gamma) logging. Neutron logging is used to estimate porosity and bulk density, and, in the vadose zone, to locate saturated zones outside a borehole or well casing. Natural gamma logs are used to evaluate downhole lithology, stratigraphic correlation, and clay content of sedimentary rocks.

Both logging techniques are based on the process by which particles of mass or energy are spontaneously emitted from an atom. These emissions consist of protons, neutrons, electrons, and photons of electromagnetic energy that are called gamma rays. Radiometric logs either make use of the natural radioactivity produced by the unstable elements U^{238}, Th^{232}, and K^{40}, or radioactivity induced by the bombardment of stable nuclei with gamma rays or neutrons.

In neutron logging, nonradioactive elements are bombarded with neutrons and stimulated to emit gamma rays. The sonde (probe) contains a neutron source, and the neutrons collide with atomic nuclei in the wall rock and emit gamma rays, which are measured by a gamma-ray detector also on the sonde. The amount of gamma radiation from neutron logging correlates directly with the proportion of water-filled pore space in a rock unit.

Natural gamma radiation logging uses a detector mounted on a sonde to measure the gamma rays produced by radioactive elements in a formation. Because different types of formations contain different amounts of radioactive elements, gamma logging is used primarily to determine lithology, stratigraphy, and the clay or shale content of a rock.

Operational Considerations

Neutron and gamma logging techniques can be used in cased holes, which means they offer a distinct advantage under some circumstances. Neutron logging requires handling of a radioactive source.

Applications and Costs

Neutron logging costs approximately $2,500 to $5,000 per well (depending on well depth and the number of other logs run at the same time). Gamma logging costs are on the order of $1,200 to $2,500 per well; approximately five to seven 100-foot wells can be logged per day.

Benefits

- Radiometric logging is suitable for both uncased and cased boreholes
- Specialized training is not required for gamma logging
- Radiometric logging is useful in characterizing rock aquifers to identify high-porosity zones that may transmit water.

Limitations

- Gamma rays detected using neutron and natural gamma logging come from the formation only within a few feet from the well
- Lithology must be determined by other logs before porosity estimates can be made using the neutron logging technique
- Neutron logging requires special training, transportation, and permits to allow handling of a radioactive source; its availability is also limited
- Neutron logging may only be allowed in cased holes in some states (e.g., Oregon)

4.2.3.5.5 Thermal Logging

Tool Description

Thermal logging is primarily used to locate water-bearing zones. It can also be used to estimate seasonal recharge or a source of groundwater. A temperature sensor, usually a thermistor mounted inside a protective cage, is lowered down a water-filled borehole. The probe is lowered at a constant rate and transmits data related to the temperature change with change of depth to surface. The natural variation of temperature with depth is called the geothermal gradient. Water-bearing zones intersected by the borehole may cause changes in the geothermal gradient, which is shown on the temperature log. Seasonal recharge effects may also be detected because the influx of recharge water changes the natural temperature regime. It is also possible to assess the source of groundwater if the regional sources have characteristic temperatures.

Operational Considerations

Thermal logging may be performed in an open or cased borehole; however, the borehole must be fluid-filled. Thermal logging should be performed several days after drilling is complete to ensure that water in the boring is representative of ambient conditions.

Applications and Costs

Thermal logging is often combined with other borehole geophysical methods. The cost of thermal logging is approximately $500 to $600 per well (depending on the total depth logged) as part of a multiple-log suite. The cost of temperature logging when no other borehole geophysical methods are used is approximately $1,500 to $2,000 per well.

Benefits

- Thermal logging is widely available, rapid, and inexpensive
- Data are easy to interpret unless internal borehole flow is present

Limitations

- Temperature measured is that of borehole fluid, which may not be representative of surrounding formation
- This technique requires a fluid-filled borehole
- Interpretation of log is complicated if internal borehole flow is present

4.2.3.5.6 Video Logging

Tool Description

Video logging a borehole can provide visual inspection of the interior of a well, detecting damaged sections of screen and confirming well construction details. In uncased boreholes, video logs can detect fractures, solution cracks, and geological contacts if turbidity in the well is low.

Operational Considerations

Video logging requires very low turbidity in the well for a successful survey. Both monochrome and color videography are available; however, color is preferred because interpretation of images is easier.

Applications and Cost

Video logging is primarily used to detect fractured bedrock and the integrity of screens and casing. Video logging may cost from $400 to $3,000 per well.

Benefits

- Video logging allows visual inspection of well interior
- Video logging is useful for troubleshooting potentially damaged casings

Limitations

- Video logging requires an open borehole and is therefore not useable with unconsolidated formations

- The borehole walls must be clean and the groundwater relatively clear

4.2.4 Soil Gas Surveys

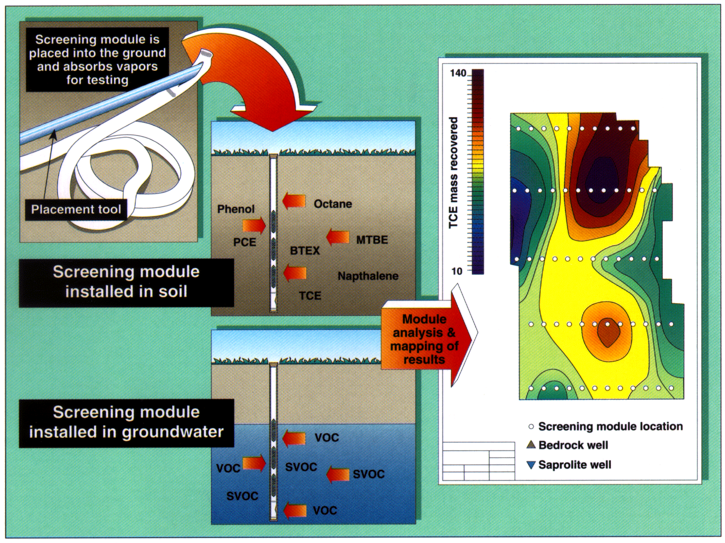
Soil gas measurements can successfully predict actual concentrations of MGP residues in soil and water. MGP residues are present in the soil as a gas because of their vapor pressure and solubility. Measuring the amount and composition of these gases can indicate the extent of source areas and groundwater plumes. Soil gas investigations, used in conjunction with physical soil and groundwater sampling, can provide a more thorough and cost-effective site investigation than borings and well samples alone. Soil gas surveys are grouped in two categories: passive and active. Passive soil gas surveys measure the relative concentration of contaminants through subsurface detectors sensitive to diffusion. Active soil gas surveys relatively quickly withdraw soil vapors using a vacuum pump system to analyze the concentration of contaminants in the vapor phase. The active gas soil gas technique provides real-time concentration data; the passive soil gas technique provides a time-integrated relative concentration that may detect less volatile compounds. Each of these methods of soil gas sampling is discussed in more detail below.

4.2.4.1 Passive Soil Gas Survey

Tool Description

Passive soil gas surveys use subsurface detectors sensitive to diffusion to measure the relative concentration of contaminants. Passive methods involve integrated sampling over time and collection of the sample on an absorbent material. Because sampling is integrated over time, fluctuations in soil gas availability resulting from changing ambient and subsurface conditions are minimized. Passive soil gas sampling does not disrupt the natural equilibrium of vapors in the subsurface as is the case with active sampling methods. Passive gas sampling only provides qualitative results because it does not measure the specific amount of contamination per unit of contaminated material. Because passive soil gas sampling occurs over a period of at least a few days, it can detect heavy organic compounds with lower vapor pressures, such as PAHs.

Gore-Sorbers® and Emflux® are both patented technologies that use passive soil gas principles. The Gore-Sorbers® Module uses a granular absorbent within an inert Gore-Tex® membrane that only permits vapor transfer into the module. Each thin, cord-like, module is placed in the shallow subsurface for a period of 2 to 4 weeks and then removed and shipped to a laboratory for analysis. Emflux® samples consist of a sampler vial containing an adsorbent cartridge. The samplers are placed at a depth of approximately 3 inches below grade for 72 hours, after which they are removed and sent to a laboratory for thermal desorption and analysis. Results of a passive gas survey is shown below.



Operational Considerations

As opposed to active gas sampling, passive soil gas sampling can be used in areas with relatively low soil permeability. Installation and retrieval of samples can be accomplished with minimal training and equipment. Soil gas samples should be taken at points deep enough to avoid background contamination from surface spills or exhaust. Installations directly beneath concrete or paved surfaces should be to a depth below the zone of lateral migration of soil gas to avoid misleading results. Depths of at least 2 to 3 feet are typically sufficient to insure good sampling. It may be difficult to obtain passive soil gas data for vertical characterization; active soil gas sampling is often used to vertically characterize contamination. Passive gas sampling may be applied directly in a saturated zone.

Application and Cost

Passive gas testing has been used for many different types of contaminants (including MGP residues) and is becoming more popular because of its low cost and flexibility in different types of soil. Using soil gas sampling data in conjunction with other site-specific data can be a cost-effective method for delineating MGP residues.

Passive soil gas testing is approximately $250 per sample location (including analysis and reporting) and $50 to $100 per location for installation and retrieval.

Benefits

- Easy to use
- Can be used in areas of relatively low permeability
- Can be more sensitive than active soil gas, soil, or groundwater sampling

Limitations

- May not correlate well with active soil sampling results
- Does not measure direct concentration
- Data at depth for vertical characterization may be difficult to collect
- Gore Sorber® passive detector must remain in situ for 14 days, whereas Emflux® passive detector must remain in situ for only 3 days

Case Study

McClellan Air Force Base (AFB)

Past disposal practices at McClellan AFB, located near Sacramento, California, from 1936 to the late 1970s, contaminated the soil and groundwater of more than 3,000 acres. Contaminants include caustic cleaners, electroplating chemicals, heavy metals, industrial solvents, low-level radioactive wastes, PCBs, and a variety of fuel oils and lubricants.

As part of a test location for innovative technologies, McClellan AFB tested the Gore-Sorber® Module, primarily to monitor VOCs (perchloroethylene [PCE] , trichloroethylene [TCE], and cis-1,2-dichloroethylene [CIS-1, 2-DCE]). A very good correlation was observed between the relative contamination levels measured by the survey and actual levels determined using active soil gas sampling (Elsevier Sciences, 1997).

Contacts

Paul Henning, Quadrel Services (Emflux® Module), (800) 878-5510

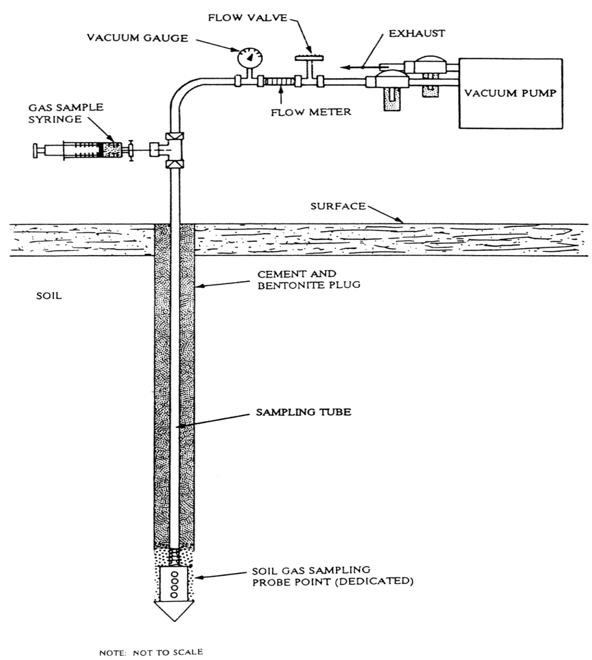
Gore Technologies (Gore-Sorber®), Mark Wrigley (410) 392-3406 and Andre Brown (415) 648-0438

4.2.4.2 Active Soil Gas Survey

Tool Description

Active soil gas surveys use a vacuum pump to induce vapor transport in the subsurface and to instantaneously collect samples of contaminants in the vapor phase. Active soil gas surveys provide a snapshot of vapor concentration in the subsurface, in contrast to passive soil gas surveys, which provide time-integrated sampling data.

Because active soil gas sampling provides real-time data, a relatively coarse sampling grid is initially used; this grid can be refined in areas of interest (e.g., areas with relatively high contaminant concentrations) for additional sample collection. The following figure shows a schematic of one type of active soil gas sampling device. (Adapted from “Handbook of Vadose Zone Characterization and Monitoring” by L.G. Wilson, et al., 1995.)



Other active soil gas sampling methods also use a vacuum pump; however, a gas sampling bag, an evacuated canister / vial, or a solid adsorbent may be used instead of a gas sampling syringe. The active soil gas sampling method that uses a solid adsorbent is similar to passive soil gas sampling techniques except that active soil gas sampling uses vacuum pressure instead of diffusion to pull the vapor sample through the solid adsorbent.

Operational Considerations

The vacuum used in active soil gas sampling disrupts the equilibrium soil gas vapor in the subsurface by forcibly drawing the vapor and soil gas from the soil matrix surrounding the sampling point. Active soil gas sampling typically must be done at least 10 to 20 feet bgs; passive soil gas sampling, by contrast, typically occurs at 3 feet bgs. It may be difficult to collect an active soil gas sample in an area of relatively low soil permeability. Active soil gas surveys may not be used in the saturated zone and may result in false negative or low soil gas concentration measurements in areas of elevated soil moisture.

Active soil gas sampling may be adversely affected by transient processes such as barometric pressure changes, earth tides, and precipitation, as well as by stationary features such as buried foundations. Active soil gas sampling data should be interpreted to account for the fluctuations these transient processes may create in the data.

Laboratory sample holding / extraction times are dependent on the specific active soil gas sampling method used. The solid adsorbent active gas sampling method requires relatively long sample holding / extraction times. The gas syringe active gas sampling method (shown in the figure above) requires relatively short sample holding / extraction times.

Applications and Cost

Active soil gas sampling is well suited to delineating areas of higher and lower VOC concentrations. Passive soil gas sampling may be better suited to measuring lower contaminant concentrations and less volatile compounds such as PAHs because of the time-integrated nature of the sampling methodology. Active soil gas sampling costs approximately $3,000 to 4,000 per day.

Benefits

- Provides real-time data
- Provides rapid results that allow the user to converge on areas of interest
- Provides a direct measure of vapor concentration
- Can be used to evaluate vertical changes in soil gas concentrations

Limitations

- Requires samples collected at least 10 to 20 feet bgs
- Cannot be effectively used in areas of relatively low permeability
- May not be effective in detecting semivolatiles (e.g., PAHs)
- May be affected by barometric and other transient processes
- Subsurface equilibrium vapor conditions disrupted by vacuum

Contacts

Tracer Research, (800) 989-9929

Transglobal Environmental Geosciences, (800) 300-6010

4.2.5 Contaminant Migration Evaluation

Three techniques for evaluating the movement and degradation of contaminants in aquifers include a Push-Pull Natural Attenuation Test, a Partitioning Interwell Tracer Test (PITT), and an In Situ Bio / Geochemical Monitor (ISM) test. Each of these are discussed in more detail below.

4.2.5.1 Push-Pull Natural Attenuation Test

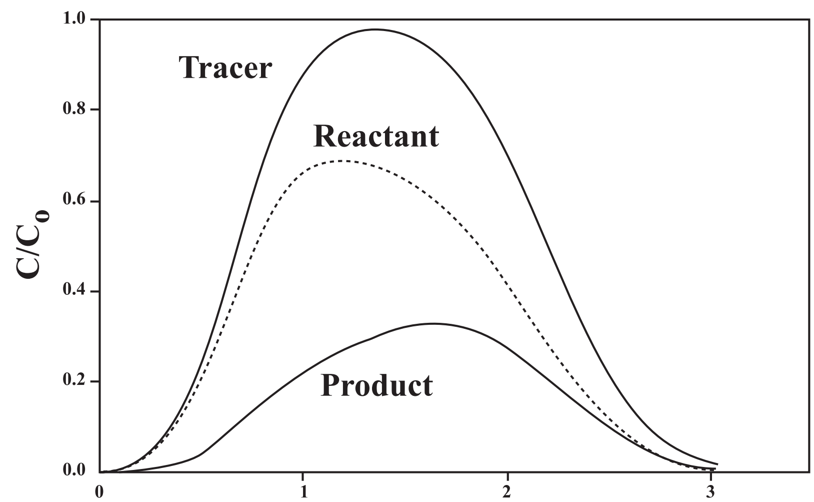
Tool Description

The push-pull natural attenuation test is an infrequently used single-well injection / extraction test used to obtain quantitative information on in situ microbial metabolic activity. A push-pull test is conducted in three steps:

1. Inject in an existing monitoring well a pulse of test solution consisting of water, a conservative tracer, and microbial substrates (electron acceptors and donors).
2. Allow the test solution to interact with indigenous microorganisms and then extract a slug of water / tracer / microbial substrates from the same well.
3. Measure the tracer, substrate, and product concentrations from the extracted slug of the test solution / groundwater mixture, and use measurements to calculate rates of microbial activities.

This method provides direct estimates of rates for microbial activity and mass balances for reactants.

The following figure shows an idealized breakthrough curve for a process generating a single product from a single reactant. The curves show the typical relationship between contaminant concentration and time, providing information on the way advection, dispersion, diffusion, and biodegradation affect contaminant movement within the aquifer.



Operational Considerations

Push-pull tests require specially trained field personnel although an individual test typically only requires a few hours, so several tests can be completed by a single operator in a day. The test solution used during the injection phase of a push-pull test is composed of various electron acceptors and donors (e.g., sodium bromide) that depend on the objectives of the sampling. The tracer selected should have a decay rate similar to or greater than the groundwater flow rate.

Applications and Cost

Push-pull tests are ideal for situations in which quantifiable estimates of microbial activity are desired for potential natural attenuation scenarios.

The cost of push-pull tests for a site contaminated with BTEX is approximately $12,000 to $15,000 for two to three wells, including analytical costs. The costs are very dependent on the specific analyses required.

Benefits

- Can document microbial metabolism, loss of degraded contaminants, production of degradation products, and estimates of zero- and first-order decay constants
- Provides in situ data (versus in an artificial laboratory environment)

- Can be used in wells that are already installed
- Can assay a wide variety of processes
- Is field tested

Limitations

- Is a fairly new test; not widely used
- Can be difficult to use when decay rate is slow relative to groundwater flow rate

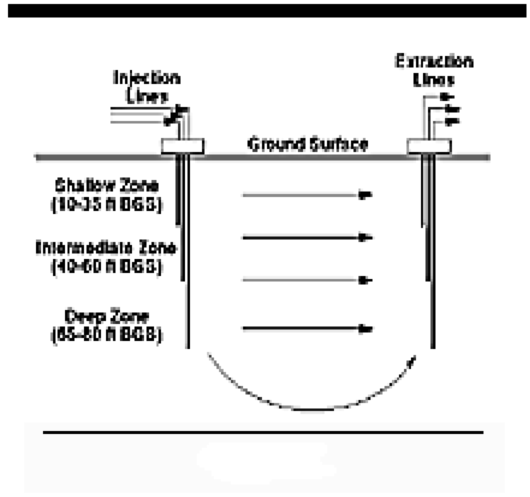
4.2.5.2 Partitioning Interwell Tracer Test (PITT)

Tool Description

The PITT is an in situ technology that measures the volume and percent saturation of NAPL contamination trapped in water-saturated and vadose zone sediments. The PITT technology is primarily used to:

- Quantify and locate NAPL contamination
- Assess the performance of remediation activities
- Quantify water saturation in the vadose zone

The technique is essentially a large-scale application of chromatography. The migration of a partitioning tracer between an injection well and an extraction well is retarded relative to a nonpartitioning tracer because it spends a portion of its residence time in the immobile residual NAPL. The chromatographic separation of the tracers indicates the presence of NAPL in the interwell zone and is used to determine the volume of NAPL present. The figure below shows a typical injection-extraction system.



The PITT technique can be used before and after an in situ remedial activity, such as surfactant flooding, to estimate the fraction of NAPL removed and the volume of NAPL remaining.

Operational Considerations

The PITT technique requires wells situated so that the potential NAPL source is within the radius of influence of the wells used to inject/withdraw the conservative and nonconservative tracers. It is important for the tracers to be nontoxic and to have nondetectable background concentrations and for the partitioning tracer to have an affinity for the particular NAPL found at the site.

Applications and Cost

The PITT technique is ideal for in situ characterization of NAPL and is limited by the well network available to perform the injection / withdrawal tests and the project budget.

The cost of PITT technology may range from $100,000 to $400,000 depending on the scale of the test.

Benefits

- Provides quantitative estimates of NAPL volume
- Can be used to design remediation methods targeting a NAPL source
- Is relatively accurate compared with other in situ tests that utilize point values or small aquifer volumes

Limitations

- Expensive
- Technology is patented
- Not economical for smaller sites
- Most application experience is with solvents

Case Study

Hill Air Force Base, Utah

The PITT technique was used at Hill AFB in 1996 to demonstrate surfactant remediation of a DNAPL-contaminated site. Partitioning interwell tracer tests were used to estimate the volume of DNAPL in place and to assess the performance of the surfactant remediation. Three constituents make up more than 95 percent of the DNAPL present at the site: TCE; 1,1,1-trichloroethane (1,1,1-TCA); and PCE. Approximately 99 percent of the DNAPL source within the test volume was recovered by the surfactant remediation leaving a residual DNAPL saturation of only approximately 0.0004. The PITT technique successfully provided quantitative estimates of DNAPL volume before and after an in situ remedial activity at this site.

4.2.5.3 In Situ Bio/Geochemical Monitor (ISM)

Tool Description

Chemical and biochemical reactions affect the geochemical composition of groundwater and the migration and persistence of inorganic and organic contaminants. The ISM allows in situ measurement of biochemical reaction rates and retardation factors for both soluble organic and inorganic compounds. The ISM maintains the geochemical integrity of sediment and groundwater and may be less expensive than collecting similar data via conventional tracer tests.

Installed below the water table, the ISM isolates a small section of the aquifer with minimal disturbance of the geological medium. Groundwater is removed from the test chamber, reactants and tracers are added, and it is reinjected into the test chamber. Samples are then collected for laboratory analysis to monitor the biological and geochemical reactions occurring within the test chamber (Solinst, 1998).

Operational Considerations

The ISM requires saturated aquifers with a hydraulic conductivity greater than 10^{-4} centimeters per second (cm/sec). The monitor is installed through the center of a hollow-stem auger with a special “trap door” cutting head and pushed into the soil using either a hydraulic ram or vibrating hammer. The ISM consists of a stainless steel test chamber, open at the bottom and bounded at the top by a set of coarse and fine mesh screens. These screens are used to draw groundwater into the test chamber. A depth-adjustable central spike with a fine mesh screen extends into the test chamber. In biodegradation studies, groundwater samples are collected via the spike. To create a one-dimensional flow system in retardation studies, water is injected through the spike and collected from the outer screens (Nielsen, 1996; Solinst, 1998).

The ISM has a relatively complex design and requires knowledgeable personnel to design, implement, and interpret tests. A numerical model may be necessary to estimate degradation rate constants from test data (Neilsen, 1996).

Applications and Cost

The ISM can be used in aquifers with a hydraulic conductivity greater than 10^{-4} cm/s where in situ biochemical reaction rates and retardation factors must be determined. The cost of ISM is approximately $3,000 for equipment purchase only, not including installation, analyses, and trained personnel (Solinst, 1998).

Benefits

- Reduces the time and cost of obtaining site-specific biological and geochemical data (as compared with injection-withdrawal and field tracer tests)
- Provides in situ measurement of biochemical reaction rates
- Provides estimated rates of denitrification during biodegradation
- Provides estimated retardation factors for organic and inorganic compounds

Limitations

- Design, implementation, and interpretation of ISM tests are complex and require knowledgeable personnel
- A numerical model may be necessary to help estimate the degradation rate constant
- Typically applicable only with permeability greater than 10^{-4} cm/sec
- Small aquifer volume tested means results may be affected by small-scale variations in aquifer properties

Contact

Solinst Canada Ltd., (800) 661-2023, www.solinst.com

4.2.6 Other Tools

Listed below are other tools and techniques that offer a range of advantages for expediting site characterization but do not fit in one of the categories previously described. These tools include:

- Microscale solvent extraction
- PAH sample filtration
- Inverse specific capacity method
- Hand-augering / trenching / pot holing
- Noise and fugitive emission controls
- Information management

4.2.6.1 Microscale Solvent Extraction

Tool Description

Conventional laboratory analysis of PAHs in soil and water matrices may take 2 weeks from the time samples are received to the time the results are released. Current EPA-approved Methods 8240, 8270, and 8310 require a 24-hour extraction period before analysis can be run. EPRI has developed a technique for analysis that requires smaller sample volumes and shorter laboratory turnaround times than conventional techniques. Because microscale solvent extraction (MSE) methods require smaller sample volumes, MSE analytical methods are ideal for alternative collection methods that yield smaller sample volumes (e.g., Geoprobe™ and Hydropunch™) (EPRI, undated).

MSE methods are microextraction techniques used by a lab to prepare samples for analysis by gas chromatography. Microextraction is defined as a single-step extraction process with a high liquid-sample-to-solvent ratio. Historically, microextraction techniques have been limited by extraction inefficiencies, in precision, and elevated detection limits. However, recent MSE methods involve multiple microextraction steps as needed to improve analyte recovery and reduce detection limits. EPRI reports that the comparison of MSE results to standard USEPA methods ranges from good to excellent.

As a screening tool, MSE methods provide quantitative results for individual PAH components at the site characterization or remediation stages of a project. Several states have approved MSE methods for specific projects either in lieu of certified laboratory analysis or as a percentage of samples being submitted to a certified laboratory for confirmation analysis.

Operational Considerations

MSE methods were originally developed for use at an on-site laboratory; therefore, these methods can easily be used in an on-site laboratory to perform expedited characterization of PAHs.

Soil sample volumes required for MSE analytical methods can be up to six times smaller than those for conventional laboratory analysis. Turnaround times for MSE methods range from 12 hours to 2 weeks; in contrast, laboratories following conventional EPA protocol may have turnaround times ranging from 24 hours to 4 weeks.

Many conventional laboratories may not have instrumentation and protocol readily available for MSE methods. Analytical laboratories chosen to use MSE methods should be interviewed and audited prior to contracting and use.

Applications and Cost

MSE methods are applicable during the site characterization or remediation stages of a project where quantified concentrations of PAHs are needed.

The cost of MSE depends on the laboratory (prices vary widely) and the types and numbers of samples to be analyzed. Analytical costs can be as much as 50 percent lower than costs for conventional analyses. In addition, using MSE methods may significantly reduce overall project costs because of rapid turnaround times on lab results (which could translate into fewer mobilizations/demobilizations of field crews) and lower sample volumes (which permit alternative drilling/sampling techniques to be implemented).

Benefits

- Small sample volumes
- Fast laboratory turnaround times
- Minimal laboratory waste
- Quantitative results for individual components

Limitations

- Relatively new procedure

Contact

Electric Power Research Institute, (800) 313-3774

4.2.6.2 PAH Sample Filtration

Tool Description

When monitoring wells are constructed or aquifers are disturbed (e.g., pumped at rates higher than natural groundwater flow), small particles called colloids are mobilized in the groundwater. Although it is common practice to require turbidity during sampling to be less than 5 nephelometric turbidity units (NTUs), in practice it may be difficult to acheive (unless low-flow sampling techniques are employed). Artificially suspended particles become entrained in groundwater at flow rates higher than the natural groundwater flow rate and these suspended particles may bias concentration data higher than true concentration levels. PAHs are relatively immobile, hydrophobic compounds that tend to sorb onto soil particles. Because PAHs have low aqueous solubility values and a high affinity to sorb onto artificially mobilized suspended particles, it may be more representative to filter

PAH samples that are collected under high turbidity conditions (Backus, 1993; and Saar, 1997).

A standard environmental filter has a pore diameter of 0.45 micrometers (mm). Research has shown that naturally transported colloids may have diameters up to 2 mm. Therefore, a drawback to sample filtering is that naturally transported colloids may be filtered, in addition to the artificially mobilized colloids, and contaminant concentrations may be understated depending on the importance of natural colloid transport at a particular site (Backus, 1993).

In deciding whether to filter groundwater samples or not, the potential for natural and artificial colloid transport should be considered. Because sampling turbid groundwater often necessitates the use of field filters, it is recommended that all attempts be made to lower the turbidity (e.g., low-flow sampling) and thereby avoid filtering altogether. Analysis of both filtered and unfiltered samples from the same location may provide an indication of the relative impact of colloidal transport; however, it cannot distinguish between natural and artificial colloidal transport.

Operational Considerations

Turbidity is often highest in formations characterized by reducing conditions and fine-grained or poorly sorted lithologies. Typically, filtering is not an issue with samples collected from higher permeability (and presumably lower turbidity) formations. For groundwater samples collected in a temporary monitoring well or borehole, turbidity will most likely be relatively high, so it may be justifiable to field filter because of the large amount of artificially entrained colloids (Backus, 1993).

The ultimate use of the sampling data should also be considered when deciding whether or not to filter a groundwater sample. In general, the following guidelines may be used in making this decision:

- Filtered samples should be used whenever groundwater samples are collected to determine whether water quality has been affected by a hazardous substances release that includes metals or chemicals susceptible to colloidal transport.
- Samples should not be filtered when a water supply well is sampled.
- For data to be used in risk assessment, unfiltered samples should also be considered if the hydrogeologist suspects that colloidal transport could be significant.
- It is generally recommended that both filtered and unfiltered samples be collected at the same time for comparison.

Several different filter types are available at equipment supply stores. Filtration may occur in an open filter funnel with filter discs (the sample is pulled through the filter with a vacuum system) or by using an in-line filter where the sample is pushed through a self-contained, enclosed filter. Many different filter sizes are available. A 0.45-mm filter should be used unless some information is known regarding the distribution of natural and artificial colloids at a particular site.

Applications and Cost

Field filtering of PAH samples is applicable to groundwater samples that have relatively high turbidity levels (e.g., greater than 5 NTUs). One key drawback, however, is that filtering also removes naturally transported colloids. The presence of naturally transported colloids should be taken into consideration when analyzing the results.

The cost of field filtering equipment is nominal compared with the cost of sample analysis and may add a small labor cost to complete the field filtering. Analyzing both filtered and unfiltered samples doubles analytical costs and raises the labor costs associated with groundwater sampling.

Benefits

- Eliminates the high bias in PAH concentration measurements introduced by artificial colloidal entrainment
- A simple technology requiring minimal training

Limitations

- PAH concentrations determined from filtered samples may not include naturally transported colloids and create a low bias
- Dissolved or colloidal contaminants may adsorb onto the filter or apparatus

4.2.6.3 Inverse Specific Capacity Method

Tool Description

The hydraulic conductivity of the interval yielding water to permanent monitoring wells is routinely estimated by pumping tests or slug tests conducted in a well. The inverse specific capacity method estimates the hydraulic conductivity of the depth interval that provides the water sample in a temporary monitoring well.

Specific capacity refers to the flow of water yielded by a well at a drawdown or drop in the water surface. The specific capacity test is usually estimated by pumping a well at a fixed rate and monitoring the drop in the level of water in the well over time. The inverse specific capacity method sets the drawdown at a predetermined level and then measures the yield required to maintain this predetermined drawdown (Wilson, 1997).

Operational Considerations

The inverse specific capacity test is conducted using the GeoProbe™ as a temporary monitoring well. Once the GeoProbe™ (or similar technology) rods are pushed to the desired depth, ¼” plastic tubing, a peristaltic pump, and a measuring cup collect the inverse specific capacity data. Typically, a peristaltic pump can lift up to 40 feet of head; therefore, when groundwater is more than approximately 40 feet bgs, the inverse specific capacity method is not feasible.

Site-specific permeability data from conventional means (pumping or slug tests) are needed to calibrate the inverse specific capacity data if quantitative data are desired. In addition, the inverse specific capacity method is only appropriate for zones with hydraulic conductivities ranging from 10^{-1} to 10^{-5} cm/sec (Wilson, 1997).

Applications and Cost

The inverse specific capacity method can be used with any direct-push drilling technique where groundwater can be sampled via suction lift using a pump on the surface. The cost is negligible assuming that a peristaltic pump and push sampler are already in use at the site. The typical time for a test ranges from 5 to 10 minutes.

Benefits

- Provides quantitative estimates of hydraulic conductivity in a temporary monitoring well
- Allows variation in horizontal hydraulic conductivity to be assessed in the vertical direction for preferential pathway identification

Limitations

- Provides hydraulic conductivity estimates for a small volume of aquifer
- Requires hydraulic conductivity values from conventional monitoring wells on site for calibration
- Only approved for zones having permeability ranging from 10^{-1} to 10^{-5} cm/sec

4.2.6.4 Hand Augering/Trenching/Pot Holing

Tool Description

Hand augering, trenching, and pot holing are well-accepted, simple techniques for gathering shallow geologic information and for surveying and delineating wastes from former MGP sites. All three methods require minimum equipment and result in the gross collection of geologic and analytical information.

Hand augers are thin-tube cylinders that are driven by hand into the ground. Typically 18 inches in length, hand augers split lengthwise to allow insertion of three stainless steel or brass rings. When driven into the ground, soil is pushed into the rings, which are then removed and used for sample analysis.

Trenching and pot holing both use equipment such as shovels or backhoes to excavate soil. Trenching is basically excavation along a single axis, often designed to create vertical walls that can then be mapped for geologic strata. Pot holing incorporates the random or sequential digging of pits and is typically used to grossly delineate the extent of MGP residues. A photograph of a typical trench is shown below.

Operational Considerations

Trenching and pot holing are easy exploratory techniques that often do not require regulatory (e.g., boring) permits. They are especially effective at large sites with few above- or underground obstructions and where labor is inexpensive. Both techniques will, however, create significant quantities of waste, which can be costly to handle and dispose of if found to be hazardous.

Similar to trenching and pot holing, hand augering is effective at sites where labor is inexpensive. In contrast to trenching and pot holing, hand augering is effective for sites where there are significant above- or underground obstructions and/or at sites where generation of wastes is a significant concern. In contrast to trenching and pot holing, hand augering is limited to the depth to which the sampler can be driven, often a maximum of 3 to 5 feet bgs.

Applications and Cost

As noted above, trenching, pot holing, and hand augering are inexpensive if labor is inexpensive. The costs for the techniques vary directly with local labor costs.

Benefits

- Can be used to expose buried objects
- Discrete and can get into tight locations (hand augering)

Limitations

- Hand augering and pot holing are depth limited
- Trenching and pot holing are visible to the public
- Borehole and slope stability may be a problem
- Waste management may be a problem with trenching and pot holing

Case Study

Marysville-1 Former MGP Site

The MGP formerly operating at PG&E's Marysville Service Center was originally located in what is now an operating substation. Because of clearance restrictions and operating limitations, standard drilling methods (e.g., hollow-stem auger drilling) could not be conducted within the substation. Hand auger sampling was initially performed within the substation in areas historically thought to contain some former MGP structures (e.g., the generating and scrubbing building, lampblack dump, and gas holder). Soil samples collected via hand augering indicated that MGP residues did exist in soil within the substation. Partial substation de-energizing was subsequently arranged, and limited access drilling (via Precision Sampling's limited-access direct-push drilling rig) was conducted to approximately 28 feet bgs within the substation.

Contact

Robert Doss, Pacific Gas and Electric Company, (415) 973-7601

4.2.6.5 Noise and Fugitive Emission Controls

Tool Description

During site characterization and remediation, noise and / or emission controls may be required for regulatory, political, and safety reasons. Sound barriers, such as curtains or berming, may be necessary to minimize noise in residential areas during 24-hour drilling or near school / community centers during the day. One primary disadvantage of sound barriers and tenting to control noise is that decreased air flow may result in the work area, so emission controls (such as ventilation blowers) may have to be increased.

Construction activities such as grading, excavation, material handling, and travel on unpaved surfaces can generate substantial amounts of dust. Water sweeping or soil stabilization may be necessary at sites where airborne dust could pose a health and safety risk. Foam suppressants and chemical applicants such as magnesium chloride are also used to control dust. A site can be completely enclosed (tented) to prevent dust migration off-site; however, ventilation of work areas may be required.

Operational Considerations

All alternatives to control noise and fugitive emissions should be considered. If, for example, several days of 24-hour construction in a residential area are required, it may be more cost effective to forgo noise control and place nearby residents in hotels during the noisiest construction. Seasonal and diurnal constraints such as cooler weather or the calmest periods of the day should be factored into the remediation schedule. To control noise from generators and other construction equipment, one alternative is to use an electrical power source or advanced muffler systems. Monitoring the effectiveness of the controls is critical. Noise monitors are readily available from field equipment catalogs and provide constant-readout, time-averaged, or peak sound levels. Airborne emission levels are often monitored visually or with the use of a hand-held meter that gives real-time measurements of dust, aerosols, fumes, and mists. Monitoring of noise or dust levels may occur at the project site perimeter if off-site migration is the primary concern; monitoring may take place close to sources if worker safety is the primary concern.

Applications and Cost

Noise and/or fugitive emission controls should be used at any site where regulatory, health, or community concerns dictate action. The cost and level of effort to implement noise and/or emission controls vary widely. Water sweeping at a smaller construction site may cost from $200 to $500 per day; renting and installing a sound barrier around a drilling operation may cost $5,000; and complete enclosure of a site could easily add tens of thousand of dollars to project costs.

Benefits

- Protects community and workers
- May satisfy regulatory requirements
- Limits noise and air pollution
- Minimizes migration/transport of contaminants during remediation

Limitations

- Noise emission control on a large scale may involve prohibitive cost and effort
- Controls may make investigations/remediations logistically more complex and/or may limit the rate of completion

4.2.6.6 Information Management

Tool Description

There is a growing awareness of the importance of information management in expediting and streamlining remedial action planning, coordination, and execution. In particular, information management tools can:

- Ensure that the quality and integrity of environmental data are maintained throughout the site investigation process.
- Facilitate data interpretation and remedial selection.

At the project level, information management tools allow geologists, engineers and project managers to plot and view site characterization data quickly and efficiently. At a management level, a database management system may provide a “big picture” of critical issues, significantly improving an environmental manager’s communications with decision makers both within their organizations and with regulatory agencies. The efficiencies gained through the effective use of database and information management systems allows resources to be shifted from labor-intensive data manipulation to analyzing data through efficient management and focusing on solutions and project closure.

A variety of commercial software packages are available to support this type of initiative. The most common characteristic of these systems is that the system architecture is designed around a common premise that all project information can be assigned a spatial address, converted to electronic formats, and entered into a geographic information system (GIS) project database.

The architecture of a GIS-based information management system must allow for multi-level participation in information use since all information is derived from a common database. Once construction of the database architecture is complete, any portion of the database can be accessed depending on user needs but not changed. This approach allows all information to be available in one location significantly reducing time spent searching for information — a common challenge without effective data management tools. The features and benefits of using a GIS-based information management system are as follows:

Feature	Benefit
Data associated with unique spatial address	High quality data integrity
Information available electronically in one location	Time accessing information reduced
Elimination of manual data handling	Reduction in data transcription errors and compounding of errors over the remainder of the project

If correctly utilized, GIS-based information management systems can reduce cycle times for completing site characterization and remediation activities.

Operational Considerations

Prior to the purchase and/or development of an information or database management system, specific project needs must be evaluated. Questions to be answered include the following:

- What kind of data may be expected?
- How much data may be expected?
- Who will be the direct users of the package (e.g., one computer operator, multiple personnel)?
- How would prospective system users interact with the system (e.g., read-only access)?
- What is the level of the users' computer literacy?
- How would the data be manipulated (e.g., tables, boring logs, cross-sections, figures, interaction with groundwater flow models)?
- How much would the client need to spend?
- What are the software's system requirements (e.g., memory, coprocessor speed)?

The answers to these questions will aid the manager in selecting the right package for the project. Options will range from sophisticated GIS packages such as ArcInfo, to less sophisticated software packages built on common computer software such as ACCESS and AutoCAD.

Applications and Cost

Data and information management packages are applicable to all projects that generate data. The level of sophistication required will vary, however, from site to site. Smaller sites may be able to use common software packages such as ACCESS, DBASE, LOTUS, and EXCESS to easily tabulate and sort data. Larger projects may look towards more sophisticated, expensive software such as ArcInfo or BOSS GMS. Costs, too, will vary considerably depending on the management system purchase, associated hardware costs, and labor costs for data entry and system maintenance.

Benefits

- Helps ensures data quality and integrity
- Facilitates data use and interpretation
- Combined with electronic deliverables from analytical laboratories, may reduce data entry costs
- May reduce labor costs associated with report preparation

Limitations

- System may act only as data repository
- No single system may be able to fulfill all project requirements

Case Study

Bordentown Gas Works, Bordentown, New Jersey

The Public Service Electric and Gas Company (PSE&G) former Bordentown Gas Works site is located in a mixed commercial and residential area in Bordentown, New Jersey. The site was used as an MGP from approximately 1853 to 1900 and as a gas distribution regulating station until 1960. Since the demolition and clearing of structures, the site has remained vacant and remains the property of PSE&G.

A pilot project was initiated by PSE&G as part of an ongoing joint effort between PSE&G and the New Jersey Department of Environmental Protection (NJDEP) to continue to streamline remedial processes associated with MGP cleanups. A remedial investigation was previously conducted at the site, indicating that remedial actions were required:

- Collect additional site characterization data to support PSE&G's remedial objective
- Conduct a remedial alternative analysis

- Prepare and submit a remedial action selection report to NJDEP. The report included a comprehensive evaluation of environmental conditions at the site using a GIS-based data management system developed and applied by Woodard & Curran, Inc.

The Woodard & Curran environmental data management system was selected to aid in data evaluation to understand the site's environmental conditions; facilitate real-time interpretation of subsequent field work activities to complete site characterization; streamline mapping and interpretation of geologic and contaminant profiles; and assist in the evaluation of viable remedial options. The system consisted of a customized software platform based on ESRI's ArcView® as the overall platform and GIS\Solutions' GIS\Key™ as the application software for environmental data. The key benefit of utilizing ArcView® is that the software has the ability to import information from a variety of software packages (including those specifically designed for environmental data management) increasing the robust performance of this system.

The data management work performed by Woodard & Curran, Inc., on this project consisted of the following tasks:

- Electronic loading of environmental data (approximately 10,000 records) into the system
- Querying of data to understand site conditions and identify data gaps in concert with the NJDEP
- Development of a supplemental investigation work plan to address data gaps
- Input of supplemental data (approximately 4,000 records) for use in mapping, assessment of environmental conditions at the site, and identification of areas of concern for evaluation of remedial alternatives
- Review of findings in a series of workshops with the NJDEP prior to preparation of the remedial action selection report

This project resulted in improvements in the overall site investigation process, including reductions in cycle time for data collection, compilation and interpretation. Supplemental field work activities filled in the data gaps and allowed the project team to focus on remedial alternatives. Field and laboratory data were in the system within one week of completion and were available to the project team for interpretation and analysis immediately thereafter. The project team conducted technical workshops to keep NJDEP apprised of results throughout the process. The data management system was used at project meetings to conduct "what if" scenarios, creating contaminant isopleths and assisting in understanding hydrogeologic features at the site. The final report included a summary of findings and conclusions that were developed in concert with NJDEP throughout the project. In summary, the application of the information management system assisted the project team and resulted in the following:

- Reductions in time and cost required to complete the site investigation
- Increased reliability of data interpretation
- A simplified way of presenting site environmental data to NJDEP and permitted them to be part of the project team evaluating site conditions and remedial alternatives in real time

Contacts

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