BENICIA SOP #18

GEOPHYSICAL TESTING

1.0 PURPOSE

1.1 This standard operating procedure (SOP) provides descriptions of geophysical methods and procedures that may be employed to identify buried objects or to define lithology. Although other geophysical methods exist, the methods most commonly used for environmental investigations are presented in this SOP.

2.0 SCOPE

2.1 This SOP applies to all project personnel and subcontractors involved with conducting geophysical investigations.

3.0 REFERENCES

3.1 Benson, Richard C., Glaccum, Robert A., Noel, Michael R., *Geophysical Techniques for Sensing Buried Wastes and Waste Migration.* December, 1982.

3.2 Brown and Caldwell, Hazardous Materials Field Procedures Manual, September, 1991.

4.0 DEFINITIONS

4.1 Geophysics. The study of the subsurface using quantitative physical methods.

5.0 GENERAL

Geophysical methods applicable to hazardous waste site investigations are generally subdivided into two categories: surface and subsurface (borehole) methods. Surface methods include but are not limited to: seismic refraction and reflection, gravimetrics, magnetometry, electrical resistivity, and ground penetrating radar (GPR). Borehole methods include but are not limited to: caliper logging, natural gamma, neutron log, resistivity (electrical-magnetic logs), and video camera.

5.1 Surface geophysical methods provide specific information on the stratigraphy, structure, and environment as well as aquifer properties. Data may include information of the types and extent of surficial material and underlying bedrock, the presence of faults, folds, fractures, karstic terrain, buried objects such as tanks and drums, and other structural features. The following describes some of the common surface geophysical techniques employed in hazardous waste investigations.

5.1.1 Seismic Refraction and Reflection Techniques. Seismic refraction is based on the fact that elastic waves travel through different geologic materials (different densities) at different velocities. In seismic exploration, the elastic waves are usually initiated by hammering on the ground, or through the use of explosives. The wave energy propagates through the subsurface encountering geologic boundaries with different elastic properties. As this happens, the velocity of wave propagation changes and wave paths are retracted according to Snell's Law. The refracted waves are then received at an array of detectors called geophones. The time delay between the initial shock (and the arrival of the wave at the geophone is recorded by a seismograph and is interpreted by the scientist to provide the required data).

The major application of seismic refraction is in the mapping of the overburden bedrock interface where overburden thickness exceeds 30 meters. Refractions from the overburden bedrock interface show up prominently on seismograms where large contrasts between acoustic layer velocities exit. To minimize the effect of low-frequency retraction arrivals, the investigator should use geophones with natural frequencies higher than those used in refraction work. Filtering capability and amplifier gain control of modern seismic data acquisition units allow these reflection events to be enhances, making it possible for a high degree of accuracy when mapping bedrock attitude.

5.1.2 Gravimetrics. Since the earth's gravitational field at a particular location is a function of the density of the surficial materials, gravity meters can be used to measure extremely small differences in the gravitational field caused by subsurface density variations; i.e. changes in rock type. Gravity methods are most useful in locating and delineating buried channels in unconsolidated deposits.

5.1.3 Magnetometry. Since local variations in the earth's magnetic field are associated with the presence of ferrous metals or magnetic minerals (such as magnetite or hematite), a magnetometer can be used to discover buried objects such as pipelines, tanks, drums, well casings and identifying geologic features that exhibit sufficient magnetic contrast.

Metal location and depth of burial can be inferred from the shape and width of the anomaly. The location of metal using magnetometry facilitates safe excavation without puncturing metal containers. Underground utilities, which are traceable with magnetics, often lie within loosely filled trenches that may provide permeable pathways for groundwater flow. Magnetrometry is used in clearing drilling sites to select locations that are free of drums, detectable under ground utilities, and other ferrous obstructions.

Under certain conditions where sufficient contrasts in magnetic susceptibilities between geologic units exist, magnetic methods may be useful in identifying geologic structures such as folding, faulting, buried drainage channels, bedrock topography, and igneous intnusions.

5.1.4 Electromagnetic. The electromagnetic (EM) method provides a means of measuring the electrical conductivity of subsurface soil, rock, and groundwater. Electrical conductivity is a function of the type of soil and rock, its porosity, its permeability, and the fluid composition and saturation. In most cases the conductivity of the pore fluids will be responsible for the measurement. Accordingly, the EM method applies both to assessment of natural geohydrologic conditions and to napping of many types of contaminant plumes. In addition, trench boundaries, buried wastes, drums, and utility lines can be located with EM techniques.

Electromagnetic methods may be used in may situations for a variety of purposes. The following list includes major uses related to investigations of hazardous waste sites:

- Defining the location of a contaminant plume (This could lead to the identification of downgradient receptors, source areas, and new directions if the conductivity of the plume (target) is distinct in comparison to the host (background) hydrogeologic setting.);
- Locating buried metal objects (e.g., drums, tanks, pipelines, cables, monitoring wells);

- Addressing the presence or location of bedrock fault/structure systems (This is important for identification of preferential pathways of water flow in bedrock.);
- Mapping grain size distributions in unconsolidated sediments;
- Mapping buried trenches;
- Defining lithological (unit) boundaries; and
- Determining the rate of plume movement by conducting multiple surveys over time.

5.1.5 Electrical Resistivity. Electrical resistivity surveys provide information about the subsurface distribution of the ground resistivity. The information can be used to infer groundwater quality and lithologic and geologic information. Both horizontal and vertical changes in ground resistivity can be mapped by resistivity surveys. In practice, resistivity surveys are mostly used to determine the vertical resistivity changes. Lateral resistivity changes are more easily mapped by electromagnetic surveys. Often, electromagnetic and resistivity surveys are used together.

Electrical resistivity (ER) data are subject to interpretation; therefore ER field results should be checked periodically and confirmed by direct methods, such as sampling or drilling. This type of conformation is essential in enforcement cases.

5.1.6 Ground Penetrating Radar. Ground penetrating radar (GPR) data are used to produce a continuous subsurface profile through the use of a linear strip chart recorder. However, while GPR is useful to define subsurface conditions, it is more limited in application than most other geophysical techniques. The following is a partial list of major uses related to hazardous waste site investigations:

- Define or locate buried drums, tanks, cables, and pipelines;
- Define boundary of disturbed versus original ground (and strata), such as a landfill or a trench;
- Map water table (limited reliability);

- Delineate stratigraphic layers, such as clay, Ull, or sands; and
- Define natural subsurface features, such as buried stream channels (preferential pathways), lenses, and voids (caves).

5.1.7 In addition, GPR may be used whenever a significant change (or differential) in electrical properties is encountered and when a change should be mapped.

5.1.8 Although GPR cannot provide definitive information on subsurface conditions, the data are desirable for several reasons. GPR can quickly provide subsurface information about a hazardous waste site. Typical productivity with conventional graphic recording GPR equipment on low-relief terrain is several line miles per day. Often, this productivity rate makes GPR a very cost-effective reconnaissance method. For example, If the objective of an investigation is to define suspected locations of buried drums, then GPR (or-other geophysical methods, electromagnetics, or magnetics) can be used to define suspected areas. Test pit excavation (or other direct methods) can be used to further explore suspected areas and can provide control for GPR data.

5.2 Borehole (subsurface) geophysical methods are used to investigate the area immediately surrounding a borehole. However, these methods can provide excellent information and resolution for vertical changes in the measured parameters. Considerable information can be obtained on the hydrogeologic conditions present at a site through the proper use of borehole geophysical logging techniques. The following descriptions provide methods which are particularly useful to hazardous waste site investigations.

5.2.1 <u>Caliper Logging</u>. Although the caliper is the simplest logging device, it is one of the most useful, both by itself and when used in combination with other geophysical instruments. This mechanical logging device consists of a probe with 1 to 4 adjustable legs that can sense the diameter of the borehole. Typical caliper equipment can measure borehole diameters as small as 4 in or as large as 24 in, to depths of 500 feet. Other models can measure boreholes to much greater depths. By knowing the exact diameter of the borehole, the contractor can determine the amount of borehole erosion that has taken place during drilling, the presence of swelling clays or resistant sandstone layers in an otherwise friable rock, fracture patterns in limestone or sandstone, the volume of filter pack or cement grout required for well completion, the positions of casing welds or joints, and areas where the casing has separated. Data from a hole caliper log is also extremely valuable in analyzing data for other types of logs where the readings are influenced by variations in hole diameter.

5.2.2 Natural Gamma. In gamma logging, measurements are made of naturally occurring radiation emitted from materials encountered in the borehole. These measurements are used as a qualitative guide for stratigraphy: correlation and determination of permeability. Certain radioactive elements occur naturally in igneous and metamorphic rocks and as depositional particles in sedimentary rocks. Clays and shales usually contain high concentrations of radioactive isotopes - chiefly potassium. Mature sands and gravels, on the other hand, contain primarily stable silica and dolomites also emit lmle radiation.

5.2.3 Neutron Log. Neutron logs are used primarily as an indicator of total porosity under saturated conditions and as a measure of soil moisture in the vadose zone. A neutron log is obtained by recording the number of neutrons encountered by a detector mounted some distance from a neutron source positioned in the borehole. Before reaching the detector, many of the neutrons emitted from the source collide with various particles, lose energy, and are captured. Most of the energy is lost in collisions with hydrogen. Because hydrogen is a principal component of water, the energy loss indicates the amount of water present in the substrate. If the energy loss is large, the amount of hydrogen in the formation must be high, and therefore the porosity is large.

5.2.4 Borehole Resistivity Logs. Borehole resistivity logs (sometimes called electric logs or F logs) provide a useful tool for assuring good well design and construction. This form of geophysical logging is easy to learn as well as being relatively cost-efficient. A good electric log gives a detailed picture of the character and thickness of the various strata at the well site and an indication of the water quality by measuring the apparent resistivity of the materials surrounding the borehole. This permits well installers to place the screen in the most desirable position with far more accuracy than merely relying on the cuttings log.

5.2.5 Video Camera. A video camera can be used to inspect borehole casings for damage, quality of completion, obstructions, etc. In addition, a camera can also be used in uncased boreholes to inspect for voids, fractures, faults, as well as to verify rock type. One advantage of this method is that it provides a permanent record of the borehole configuration in the form of a video tape.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** is responsible for ensuring that the selected geophysical method(s) will meet the objectives of the geophysical survey.

6.2 The **Field Supervisor** is responsible for contracting and coordinating the geophysical contractor. The Field Supervisor must coordinate with the Project Manager and the Field Geologist to ensure that the most applicable geophysical method is being employed, and that the geophysical survey data quality and quantity is adequate to fulfil the survey objectives.

6.3 The **Field Geologist** is responsible for ensuring that the geophysical contractor conducts the geophysical survey in the appropriate methods as coordinated with the Project Geologist and the Project Manager.

7.0 PROCEDURE

This section describes the general procedures for the geophysical methods described in Section 5.0. Exact procedures may vary from contractor to contractor.

7.1 SURFACE AND GEOPHYSICAL METHODS.

7.1.1 Siesmic Refraction. Mechanical and contained explosive sources are used in populated areas or when desired penetration depths are less than 100 to 300 feet. Hammer surveys are conducted striking a steel plate coupled to the ground with a sledge hammer. An initial switch on the hammer is connected to the seismic data acquisition system with a cable, enabling the moment of hammer impact to be accurately recorded. Another technique commonly used is the weight drop of '"thumper" technique. Typically, a truck-mounted 3-ton weight is dropped from a height of 10 feet. The instant of group impact is determined by a sensor on the weight.

Explosive sources are used sparsely in populated areas or when penetration depths are greater than 100 to 300 feet. Two types of chemical explosives, gelatin dynamite and ammonium nitrate, are commonly used in explosion surveys and are detonated in seated boreholes. Gelatin dynamite is a mixture of gelatin, nitroglycerin, and an inert binder material that can be used to vary the strength of the explosion. Ammonium nitrate is a fertilizer that is mixed with diesel fuel and is detonated by the explosion of a primer. A charge of about 1 pound of explosives is usually sufficient to obtain penetration depths ranging from approximately 100 to 300 feet. Explosive sources generate wave fronts that are very steep and show up as distinct arrivals on seismograms. These sharp pulses, however, are more likely to cause damage to nearby structures. It may not be advisable to use explosive sources in hazardous waste sites where unknown gases or buried containers may be present.

7.1.2 Gravimetrics. The basic procedure is accomplished in the following way: first, a grid network or traverse of sampling points is established across the subject area. Measurements of the gravitational field are then taken at the various pre-determined points using a man-portable gravity meter. Available computer software packages can be used to plot three-dimensional maps showing the determined subsurface configuration.

7.1.3 Magnetometry. Magnetic measurements are usually taken either at equally spaced stations located across a rectangular grid or at equal intervals along several profile lines. The spacing of the stations depends on the target size. In general, the spacing between stations should be approximately one-fourth of the lateral extent of the target. For a single 55-gallon drum, the maximum distance at which the station can be detected is typically 10 to 15 feet, and the grid spacing can be designed accordingly. The closer the stations are spaced, the better the resolution becomes and the better the probability of detecting anomalies. More stations are required to - cover the same area, however, and the time required to conduct the survey increases correspondingly. It is helpful to lay out the survey grid so that the lines are oriented perpendicular to the strike of the target. If this orientation is not known, then north-south grid lines are preferable.

7.1.4 Electromagnetics. Once the EM survey objectives have been clearly defined, the existing information has been reviewed, and reconnaissance of the site has been conducted, attention should be given to the design of the geophysical survey. The detail required of an EM survey is a primary factor in designing and planning fieldwork. It the purpose of performing EM work onsite is to define a large geologic feature, then a grid using a wide (100- to 1,000 foot-line spacing may be needed. Some instruments are capable of providing a continuous data profile, which makes them less likely to miss small conductors than the typical discrete measurement EM instruments. The importance of designing and implementing a grid system tied into existing permanent features (such as roads and buildings) cannot be overstated. This permanent feature will allow the grid to be reoccupied in the field to place drill holes and monitoring wells. Furthermore, additional surveys may be conducted on the site using other geophysical techniques or the same technique to provide an indication of plume movement. These surveys will help in orienting maps and diagrams that are produced later and in defining targets.

7.1.5 Electrical Resistivity. Electrodes are typically arranged in one of several patterns, called electrode arrays, depending on the desired information. Electrical resistivity techniques can determine the vertical subsurface resistivity distribution beneath a point. In this type of survey, called vertical electrical soundings, the electrode array is expanded systematically and symmetrically about a point. For each set of electrode spacings, apparent resistivity is determined from measurements of potential and input current. The resultant plot of apparent resistivity versus electrode spacing is interpreted to provide the subsurface resistivity with depth distribution at that one particular point. Examples of three common arrays are given in Figure 4-4. The Wenner and

Schlumberger arrays are somewhat more common than the Dipole-Dipole and other arrays. These arrays (Wenner, Schlumberger) start with a small electrode spacing that is increased to permit deeper penetration for sounding.

Data can be collected at randomly located stations or along survey lines. If vertical electrical soundings ate performed to obtain resistivity changes with depth, then the soundings are positioned where the information is most useful. If measurements are made to map lateral resistivity changes, then the survey is best performed on a grid or on survey lines. The station spacing will be determined from the target size.

7.1.6 Ground Penetrating Radar. Once the GPR survey objectives have been clearly defined, the-existing information has been reviewed, and reconnaissance of the site has been conducted, attention should be given to the design of the geophysical survey. The detail (coverage, resolution) required of a radar survey is a primary factor in designing and planning fieldwork. If the survey is to provide reconnaissance information on the possibility of buried drums onsite, then a grid using a wide (50 to 200-foot) line spacing may be appropriate. If the purpose is to define as many drum locations as possible (such as for removal), then a detailed survey is probably required (10-2 foot line spacing). The importance of designing and implementing a grid system tied into existing "permanent" features (such as roads and buildings) cannot be overstated. This design will allow the grid to be reproduced (if required) for enforcement purposes and will also help to locate anomalous areas for future fieldwork (such as sampling, drilling, or digging test pits) by use of the grid for points of reference. Under certain circumstances, a reproducible grid may not be needed, such as if the raw field data are going to be used to direct other field operations, but this situation is not typical.

The anticipated size of the target compared with the proposed survey areas should have an impact on the detail of the GPR survey grid. To reliably locate a suspected target would require more effort (such as denser line spacing or use of a higher resolution transmitter antennae) for a smaller target than would be required for a larger one. Reliably locating a target does not mean that the target will be clearly defined in the data. Site-specific factors such as poor field methods, target depth, and background noise may cause a target to be overlooked or misinterpreted.

7.2 BOREHOLE GEOPHYSICAL METHODS. This section presents the general procedures for Borehole Geophysical Methods.

7.2.1 Caliper Logging. To operate the hole caliper, it is merely lowered into the borehole and the readings recorded at the surface as the caliper is withdrawn. Most calipers have a surface recorder that shows the diameter of the borehole as a function of depth. Some caliper cables are marked in feet or meters and can be lowered by hand or by a drum winch.

Caliper tools can be calibrated by placing the legs or feelers inside a cylinder or ring of known diameter. If any drift is anticipated, enough points should be plotted inside the casing (a known diameter) to establish the linearity of the system's response. One inch of chart width per inch of hole diameter provides enough sensitivity to locate fractures.

7.2.2 Natural Gamma. Gamma logging has a fundamental advantage over electrical logging: it can be done in either cased wells or in open boreholes containing air, water, or drilling fluid whereas electrical logging can be done in uncased wells filled with fluid. As a result, gamma logging can be done in existing wells where the original logs have been lost or destroyed. The electronic equipment of a gamma ray logger consists of a detector, a regulator, and electronic timer, and

7.2.3 Neutron Log. Neutron logs can be done in cased or open holes that can either be filled with fluid or be dry. The depth of neutron penetration into a formation depends on the porosity, hole diameter, and spacing between the source and detector. For high porosity materials, the depth of penetration may be 6 meters or less, whereas, for lower porosity materials it may be up to 2 feet.

7.2.4 Borehole Restitution Logs. To obtain an electric log, one or more electrodes are suspended on a conductor cable and lowered into a borehole filled with drilling fluid or water. An electric current is forced to flow from these electrodes to other electrodes that may be in the borehole or placed in the ground near the top of the well. The electric logging instrument then measures the current loss (resistance between two electrodes). Changes in resistance of the entire circuit are recorded against depth to produce a graph or curve called the electric or E-log. These logs are then compared to similar logs produced in other neighboring wells to provide geologic correlation of the stratigraphy. A limiting factor in this method is that logging can be done only in boreholes that do not have casing and are filled with drilling fluid or water.

7.2.5 Video Camera. The basic procedure involves the lowering of a camera into the borehole which relays video images to a monitor which can be viewed in real-time.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE FORMS

8.1 The results of each geophysical survey shall be placed in the project file at the conclusion of the project.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #19

SOIL GAS SAMPLING

1.0 PURPOSE

1.1 This standard operating procedure (SOP) provides descriptions of soil gas sampling methods and procedures.

2.0 SCOPE

2.1 This procedure applies to all project team personnel and subcontractors involved in soil gas sampling procedures.

3.0 REFERENCES

3.1 Brown and Caldwell, Hazardous Materials Procedures Manual, September, 1991.

4.0 DEFINITIONS

Not applicable

5.0 GENERAL

5.1 Virtually all volatile organic compounds that are present in the groundwater volatilize and move upward through the saturated zone and into the vadose zone. This is due to the high vapor pressure and low aqueous solubility of these compounds.

5.2 Soil gas may be generated by biological, chemical, and physical decomposition of waste. Waste characteristics such as type, source, and quantity; climatic conditions; and the geologic location of the waste in or into the subsurface can affect the rate of decomposition and gas production.

5.3 Biological decomposition is found in most active and closed landfills containing organic waste.

5.4 Liquids stored or spilled from underground tanks and pipelines are likely to undergo chemical decomposition.

5.5 Sampling and measuring the levels of volatile organics in the soil gas can aid in defining the extent of subsurface contamination, including locating the source and identifying the plume migration path. The vapor is obtained by placing a collector at an appropriate depth, bringing the vapor to the surface and then analyzing the vapor at the site or taking a vapor sample to a laboratory. By detecting subsurface VOC contamination, soil gas surveys can identify sources of soil contamination and map groundwater VOC contamination plumes.

5.6 Soil gas monitoring locations may be set up on a grid network or, if the source of contamination is known, in a concentric circle pattern out from the source. Following an initial screening of the entire area, a concentrated grid may be employed around "hot spots" for further delineation of concentration gradients, pinpointing of a source, or determination of the extent of a plume.

5.7 Getting to and locating the desired soil depth to take the sample can be accomplished using one of several methods. For shallow soil gas samples, a metal pipe with a pointed end (called a probe) is driven into the ground. The probe has an array of holes or slots in its side at a known distance from the driving end. Manual drivers include the slide hammer and the fence post driver. Generally, manual driving of the probe limits the sampling depth to 4 to 9 feet. Electric hammers and truck mounted hydraulic drive units can be used to drive or hammer probes easily to 20 feet. Deeper soil gas samples can be collected using a hollow stem auger drill rig. Mechanical drivers and rams are usually faster than manual drivers.

The following are techniques for performing soil gas surveys:

5.8 The following types of passive ground probes may be used:

5.8.1 <u>Downhole Isolation Flux Chamber</u>. This device uses an enclosure (flux chamber) for sampling gaseous emissions. Clean dry air is added to the chamber at a fixed rate. The concentration of the parameters of interest is measured at the chamber exit with a portable photoionization detector (PID) or flame ionization detector (FID). Once a steady state emission rate is obtained, a sample may be collected for gas chromatograph (GC) analysis with a gastight syringe or an air sampling bag or chamber.

5.8.2 <u>Accumulator Device</u>. These devices involve collecting soil gas and concentrating it over time. The sampling period is based on the sampling rate, the anticipated concentration of the contaminants, and analytical sensitivity. The accumulation device provides an integrated sample that averages fluctuations in soil gas concentrations.

5.8.3 Pipe Probes. These devices involve the use of a piece of small-diameter tubing placed in an auger hole. The tubing has a hole in the leading end that allows the soil gas to enter the pipe. At the top end, a sampling port or a tube is placed in the probe to allow collection or detection of the soil gas sample with an accumulator device, portable survey equipment, or a gastight syringe with GC.

5.8.4 Drive Probes. These devices have an attached drive tip that is used to drive the probe to the desired depth. This eliminates some of the disturbance of the soil around the probe associated with the drilling of passive probes.

5.8.5 Pipe Drive Probes. These devices involve the use of a perforated tube with a drive tip. The perforations on the leading edge allow soil gas to enter the probe. The top edge has a drive cap and a sampling port. The probe is driven to the desired depth, and a gas sample is collected as it is in the passive ground pipe probe.

5.8.6 Sleeve Probes. These devises consist of an outer tube with a drive cap and sample port on the trailing edge and an open coupling on the leading edge. A drive point attached to a rod slides into the outer tube. After the probe reaches the desired depth, the outer sleeve is raised, and a sample can be collected from the sample port with the methods used in the pipe probe.

5.9 Air piezometers can be installed to obtain soil gas concentrations at depth, or in areas inaccessible to other monitoring techniques. Single or multiple probes can be installed in a borehole. Piezometers are typically placed in high-permeability zones. Installation of piezometers requires use of a drill rig. It is essential that any monitoring wells tested with these devices be airtight and not contain volatile glues or solvents. After installation, allow at least 24 hours before collecting subsurface gas samples.

5.9.1 Packer gas piezometers are installed in the same manner as the air piezometer. They have larger or numerous screened areas and may be installed in series for isolation of the desired level for sampling. The sample probe has an inflatable packer that isolates the bottom of the well during sampling. A pump is connected to the probe, and a sample is withdrawn and analyzed.

5.10. Limitations of soil gas surveys include:

5.10.1 Not effective where bedrock or water table is close to surface;

5.10.2 Clays may shield vapors from contaminants. Clays may make determination of source difficult;

5.10.3 Degradation of contaminants may not be realized;

5.10.4 Temperature and barometric pressure, humidity, and recent rainfall can affect soil vapor readings. Samples used in comparative studies should be obtained in as short a period of time as possible; and

5.10.5 Manmade structures such as buried walls, objects or trenches may make soil gas survey data difficult to interpret.

6.0 RESPONSIBILITIES

6.1 Each **Project Manager** shall assure that the sampling procedures used to obtain samples will represent the environment being investigated. Trace levels of contaminants from external sources will be eliminated through the use of good sampling techniques and proper selection of sampling equipment.

6.2 The **Sampling Team Leader** shall ensure that specified sampling procedures are followed; samples are labeled, handled, and controlled correctly; and strict chain of custody (COC) is initiated, maintained, and documented.

6.3 Personnel responsible for collecting soil gas samples will do so in accordance with this SOP.

7.0 PROCEDURES

7.1 Soil vapor probe installation includes the following procedures:

7.1.1 Select location for soil vapor probe installation and label on site map;

7.1.2 Soil vapor probe can only be installed in soil. It can not penetrate asphalt, pavement, or bedrock. If site is paved, cut a hole in the pavement at the desired location;

7.1.3 Install Teflon® tubing into soil vapor probe per manufacturers instructions. Make sure connections are tight. Provide adequate length of tubing for desired installation depth and for sample collection;

7.1.4 Soil vapor probe is installed using a slide hammer or electric rotary hammer drill to push probe into soil.

7.1.5 Attach drive extensions as needed while following manufacturers instructions to achieve required depth for soil vapor sampling; and

7.1.6 If soil vapor probe screened interval is provided with a retractable assembly, then retract screen cover per manufacturers instructions to expose screened interval.

7.2 Soil vapor sampling procedures include the following:

7.2.1 Teflon tubing is utilized for soil vapor extraction. Make sure an airtight seal is maintained at all times during soil vapor extraction to prevent ambient air leaks (sample dilution) into vapor tubing. Check connections at ground level, at sample canister and at any valves or connections. An in-line vacuum gauge may be used to evaluate the vacuum of the sampling system;

7.2.2 Review instructions and packing list provided with sample canister sample container or equivalent. Call laboratory with any questions or discrepancies. The laboratory should be advised of the contaminants to be analyzed and required detection limits prior to shipment to ensure proper canister preparation;

7.2.3 Install particulate filter provided with canister at canister inlet;

7.2.4 Install canister along soil vapor extraction tubing line prior to vacuum pump. Keep canister inlet valve closed until ready for sample collection;

7.2.5 Record initial vacuum of canister on the canister tag, and in the field logbook. Initial canister vacuum should be approximately 28 inches Hg;

7.2.6 Purge sample line with vacuum pump for a minimum of 5 minutes per 5 feet of depth to vapor screen interval. Canister inlet valve remains closed during purging of the sample line. Vacuum pump shall be of oil-less design and capable of pulling a minimum vacuum of 25 inches H_2O. Keep in mind the requirement for electrical power to run the vacuum pump if it is not hand operated.

7.2.7 A sample for field analysis can be collected at the vacuum pump outlet in a tedlar bag or can be directly connected to a PID or FID. Taking a field measurement at the completion of the purge cycle is recommended in order to get an idea of soil vapor concentrations and to ensure that there are no system air leaks;

7.2.8 Record vacuum in line, depth to soil vapor extraction screening, length of purge time, and well vapor concentrations. Recording system vacuum is recommended but not required as not all vacuum pumps come with vacuum gages. A vacuum gage can also be installed in line with use of a tee;

7.2.9 Prepare sample label;

7.2.10 Following well purging, open inlet valve to canister with vacuum pump still on. Canister is under a vacuum and will pull the sample from the vapor extraction tubing. Sampling should be complete within 20 seconds. Close canister inlet valve;

7.2.11 Record final vacuum of canister on the COC, canister tag, and in the field logbook. Final vacuum should be approximately 2- to 10-inches Hg; and

7.2.12 Prepare COC for laboratory analysis and submit to the laboratory. Hold time for canister is 14 days. Hold time for tedlar bag is 3 days.

7.3 The removal of the soil vapor probe includes the following procedures:

7.3.1 Some manufacturers provide soil vapor probes which can be removed following sample collection and moved to another location for reuse in soil vapor sample collection. The soil vapor probe tip and drive extension threads can be damaged during removal without proper tools. Therefore, it is recommended that a retrieval jack be utilized for probe removal in order to extend the equipment life;

7.3.2 Decontaminate soil vapor probe upon removal. Make sure vapor extraction tubing is not damaged during decontamination procedure. Replace any defective tubing. Make sure tubing is dry inside prior to reuse; and

7.3.3 Fill hole following probe removal with native soil, if less than 5 feet deep. Otherwise, abandon boreholes as specified in SOP.

7.4 The procedures specified in the project team SOP 11.0, Sampling Equipment Decontamination, shall be followed for decontamination of sampling equipment and for personnel decontamination. Decontaminate all probes, and other sampling devices prior to each sampling event. If new, dedicated equipment is used, thoroughly decontaminate and rinse it with distilled water before placement in the well. Soil gas probes must be thoroughly dried before use. An over may be used to dry the soil gas probes. Mobile decontamination supplies shall be provided so that equipment can be decontaminated in the field. Check all measuring devices for proper operation. Decontaminated solutions shall be placed in containers for disposal

7.5 Quality Assurance/Quality Control (QA/QC) samples are collected during soil gas sampling according to the site-specific QAPP or FSIP.

QA/QC samples may be labeled with QA/QC identification numbers (or fictitious identification numbers if blind submittal is desired), and sent to the laboratory with the other samples for analyses.

7.5.1 Field Blanks. A field blank is used to assess possible contamination resulting from deionized water, sample containers, or laboratory procedures. An empty sample canister or bag is taken to the field and filled at a contaminant free area with air upwind of site. The blank sample is assigned an identification number, stored in a cooler, and shipped to the laboratory with the other samples. To minimize potential bias by the receiving laboratory, blank samples are submitted blind.

7.5.2 Quality Assurance Duplicate Samples. QA duplicate samples are used to assess laboratory accuracy in constituent identification and quantification.

QA duplicate samples consist of representative sample volumes from one soil gas sampling location. If the QC schedule indicates a duplicate sample is to be collected, the above ground soil gas sampling apparatus will be modified to collect both samples at the same time. To maximize the information available in assessing total precision, duplicate samples should be collected from locations of varying contaminant concentrations. Field measurements, visual observations, and past sampling results and information on site operations may be used to select appropriate locations for duplicate analyses. Equal volumes are submitted to two or more laboratories for analysis using identical methods for preservation, packaging, and submission. The party receiving the QA duplicate sample completes a "Receipt for Samples Form" and provides a copy to the project team. The results are compared as a check on laboratory accuracy. Because two samples are analyzed, environmental variability and precision (from one location to another) is assessed.

7.5.3 Field Duplicate Samples. Field duplicate samples are collected to assess the total precision of field and laboratory components of the field investigation. Field duplicate samples are similar to QA duplicate samples except that the samples are stored in the same cooler and shipped to the same laboratory. Whenever possible, the sample identification numbers for the characteristic sample and its duplicate shall be independent such that the receiving laboratory is not able to distinguish which samples are duplicates prior to analysis. This minimizes the potential for laboratory bias.

7.6 Samples are identified, handled, and recorded as described in this SOP and in accordance with standard sample handling protocols indicated in the site-specific QAPP.

7.7 Field notes are kept in a bound field logbook. The following information specific to soil gas sampling is recorded using waterproof ink:

7.7.1 Location and sample number;

7.7.2 Date and time of sampling;

7.7.3 Initial and final vacuum reading;

7.7.4 Analyses to be performed by the laboratory;

7.7.5 Person performing sampling;

7.7.6 Purge start/stop times;

7.7.7 Pumping rate (if applicable);

7.7.8 Field parameter measurements during purging;

7.7.9 Sample volume, number, and container types;

7.7.10 Method of sample collection;

7.7.11 QA/QC samples collected; and

7.7.12 Irregularities or problems.

8.0 RECORD KEEPING REQUIREMENTS

Not applicable

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #20

SLUDGES AND SEDIMENTS

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to provide procedures for sampling sludges and sediments.

2.0 SCOPE

2.1 This SOP applies to all project team sampling sludges or sediments.

3.0 REFERENCES

3.1 Brown and Caldwell, Hazardous Materials Field Procedures Manual, September 1991. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1975.

4.0 DEFINITIONS

4.1 Sludge. Semi-dry materials ranging from dewatered solids to high viscosity liquids.

4.2 Sediment. Deposited material that has settled out of suspension from a liquid.

5.0 GENERAL

5.1 On occasion sludges and sediments are exposed by evaporation, stream rerouting, or other means of water loss. In these instances they can be readily collected by soil or sludge collection methods. In collecting sludge and sediments samples, care must be taken to minimize disturbance and soil washing.

5.2 Sludges can often be sampled by the use of a stainless steel scoop or trier. Frequently, sludges form as a result of settling of the higher density components of a liquid. In this instance the sludge may still have a liquid layer above it. When the liquid layer is sufficiently shallow, the sludge may be scooped up by a device such as the pond sampler, or by using a thin-tube sampler. The latter is preferable as it results in less sample disturbance and will also collect an aliquot of the overlying liquid, thus preventing drying or excessive sample oxidation before analysis. Sludges which develop in 55 gallon drums can usually be collected by employing the glass tubes used for the liquid portion sample. The frictional forces which hold the sludge in the tube can be supplemented by maintaining a seal above the tube. When the overlying layer is deep, a small gravity corer such as those used in limnological studies will be useful. Gravity corers, such as Phlegers, are easier to preclean and decontaminate than piston type corers.

5.3 If the sludge layer is shallow (less than 30 centimeters), corer penetration may damage the container liner or bottom. In this instance a Ponar or Eckman grab sampler may be applicable, as grab samplers are generally capable of only a few centimeters of penetration. Of the two, Ponar grab samplers are applicable to a wider range of sediments and sludges. They penetrate deeper and seal better than the spring-activated Eckman dredges, especially in granular substrates.

5.4 In many instances sediments and sludges can be collected with a peristaltic pump. This method is limited to slurried samples less than approximately 20 percent solid. The weight of the material will also greatly reduce the lift capacity of the pump, however, it may still be useful in extending the reach of the sampler laterally toward the center of a vessel. In slurries not fully agitated, a bias may also be introduced toward the liquid portion of the material.

5.5 Sediments can be collected in much the same manner as described above for sludges; however, a number of additional factors may be considered. Streams, lakes, and impoundments, for instance, will likely demonstrate significant variations in sediment composition with respect to distance from inflows, discharges, or other disturbances. It is important, therefore, to document exact sampling location by means of triangulation with stable references on the banks of the stream or lake. In addition, the presence of rocks, debris, and organic material may complicate sampling and preclude the use of or require modification to some devices. Sampling of sediments should therefore be conducted to reflect these and other variants.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** is responsible for ensuring that sludge and sediment sampling procedures are conducted in compliance with this SOP.

6.2 The **Field Supervisor** is responsible for ensuring that the proper sampling equipment and methodology is used for the collection of sludge and sediment samples. The Field Supervisor is also responsible for ensuring that the integrity of the samples is maintained from collection through delivery to the laboratory and that the appropriate shipping and handling procedures are followed.

6.3 The **Staff Geologist** is responsible for proper sample collection including adequate decontamination procedures and sample packaging.

7.0 PROCEDURES

7.1 Sludge and sediment samples are collected using the simple laboratory scoop or garden type trowel. This method is more applicable to sludges but it can be used for sediments provided the water depth is very shallow (a few centimeters). It should be noted, however, that this method can be disruptive to the water/sediment interface and might cause substantial alteration. Undisturbed samples cannot be collected using this method. Procedures include the following:

7.1.1 Sketch the sample area or note recognizable features for future reference;

7.1.2 Insert scoop or trowel into material and remove sample. In the case of sludges exposed to air, it may be desirable to remove the first 1-2 cm of material prior to collecting sample;

7.1.3 If compositing a series of grab samples, use a stainless steel mixing bowl or Teflon tray for mixing;

7.1.4 Transfer sample into an appropriate sample bottle with a stainless steel lab spoon or equivalent;

7.1.5 Check that a Teflon liner is present in cap if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration is usually the best approach supplemented by a minimal holding time;

7.1.6 Label the sample bottle with appropriate information. Be sure to label carefully and clearly, addressing all the categories or parameters. Complete all COC documents and record in the field log book; and

7.1.7 Decontaminate sampling equipment after use and between sample locations according to the guidelines presented in SOP 11.0.

7.2 Hand corers are applicable to the same situations and materials as the scoop described previously. It has the advantage of collecting an undisturbed sample which can profile any stratification in the sample as a result of changes in the deposition.

Some hand corers can be fitted with extension handles which will allow the collection of samples underlying a shallow layer of liquid. Most corers can also be adapted to hold liners generally available in brass, polycarbonate plastic or Teflon. Care should be taken to choose a material which will not compromise the intended analytical procedures. Procedures include the following:

7.2.1 Inspect the corer for proper precleaning, and select sample location;

7.2.2 Force corer in with smooth continuous motion;

7.2.3 Twist corer then withdraw in a single smooth motion;

7.2.4 Remove nosepiece and withdraw sample into a stainless steel or Teflon® tray;

7.2.5 Transfer sample into an appropriate sample bottle with a stainless steel lab spoon or equivalent;

7.2.6 Check that a Teflon® liner is present in cap if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration is usually the best approach supplemented by a minimal holding time;

7.2.7 Label the sample bottle with the appropriate information. Be sure to label carefully and clearly, addressing all the categories or parameters. Complete all COC documents and record in the field log book; and

7.2.8 Decontaminate sampling equipment after use and between sample locations as required by procedures in SOP 11.0, Sampling Equipment Decontamination.

7.3 A gravity corer is a metal tube with a replacement tapered nosepiece on the bottom and a ball or other type of check valve on the top used for sampling bottom sludges or sediments. The check valve allows water to pass through the corer on descent but prevents a washout during recovery. The tapered nosepiece facilitates cutting and reduces core disturbance during penetration.

Most corers are constructed of brass or steel and many can accept plastic liners and additional weights. Corers are capable of collecting samples of most sludges and sediments. They collect essentially undisturbed samples which represent the profile of strata which may develop in sediments and sludges during variations in the deposition process. Depending on the density of the substrate and the weight of the corer, penetration to depths of 75 cm (30 inches) can be attained.

Care should be exercised when using gravity corers in vessels or lagoons that have liners because penetration depths could exceed that of the substrate and result in damage to the liner material. Procedures for use include the following:

7.3.1 Attach a precleaned corer to the required length of sample line. Solid braided 5 mm (3/16 inch) nylon line is sufficient; 20 mm (3/4 inch) nylon, however, is easier to grasp during hand hoisting;

7.3.2 Secure the tree end of the line to a fixed support to prevent accidental loss of the corer;

7.3.3 Allow corer to free fall through liquid to bottom;

7.3.4 Retrieve corer with a smooth, continuous lifting motion. Do not bump corer as this may result in some sample loss;

7.3.5 Remove nosepiece from corer and slide sample out of corer into stainless steel or Teflon® pan;

7.3.6 Transfer sample into appropriate sample bottle with a stainless steel lab spoon or equivalent;

7.3.7 Check that a Teflon® liner is present in cap if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration is usually the best approach supplemented by a minimal holding time;

7.3.8 Label the sample bottle with the appropriate information. Be sure to label carefully and clearly, addressing all the categories or parameters. Complete all COCs and record in the field log book; and

7.3.9 Consult SOP 11.0 for decontamination requirements and decontaminate sampling equipment after use and between sampling locations.

BENICIA SOP #21

WELL AND PIEZOMETER INSTALLATION

1.0 PURPOSE

1.1 This standard operating procedure (SOP) provides procedures and requirements for proper installation of wells and piezometers after completion of the well boring.

2.0 SCOPE

2.1 This SOP applies to all project team personnel and subcontractors installing wells for environmental investigations and monitoring programs.

3.0 REFERENCES

3.1 Aller, L., et al. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells: National Water Well Association, U.S. Environmental Protection Agency (USEPA), EPA 600/4-89/034.

3.2 American Society for Testing and Materials, (ASTM) Standard on Groundwater and Vadose Zone Investigations 1994; Standard 5092-90, Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers, pp. 278-289.

3.3 Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske. 1985. Practical Guide for Ground-Water Sampling, EPA/600/2-85/104, pp.47-72. September.

3.4 California Department of Water Resources (DWR). 1990. California Well Standards, DWR Bulletin 74-90 (supplement to Bulletin 74-81). January.

3.5 California DWR. 1991. California Well Standards, DWR Bulletin 74-91 (supplement to Bulletin 74-81). June.

3.6 California DWR. 1981. Water Well Standards, DWR Bulletin 74-81. December.

3.7 Driscoll, F.G. 1986. Groundwater and Wells, , pp. 395-463, Johnson Filtration Systems. Second Edition.

3.8 Todd, D.K. 1980. Ground-Water Hydrology, Second Edition,, p. 164-193. John Wiley & Sons.

3.9 United States Environmental Protection Agency (USEPA). 1991. Groundwater Volume II: Methodology, EPA/625/6-90/016b, pp. 1-21. July.

3.10 USEPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1, pp. 71-94. September.

4.0 DEFINITIONS

4.1 Annular Seal. A positive seal between the boring wall and the well casing to prevent the migration of contaminants to the sample zone from the surface or intermediate zones and to prevent cross-contamination between strata. Annular seals must be impermeable and resistant to chemical or physical deterioration. The annular seal typically consists of a base of Portland® cement and water.

4.2 Annular Space or Annulus. The space between the boring wall and the well casing, or the space between the casing pipe and liner pipe.

4.3 Centralizers. A device that is mechanically fastened to the well casing used to center the casing in the boring to ensure effective placement of filter pack or grout.

4.4 Monitoring Well. Any artificial excavation constructed to provide access to groundwater in order to measure groundwater levels and procure groundwater samples which accurately represent *in situ* conditions. Monitoring wells may be temporary (microwells) or permanent.

4.5 Filter Pack. A chemically inert, uniformly graded (sand or gravel) that is placed in the annulus of the well between the well screen and the surrounding formation to stabilize the adjacent formation.

4.6 Surge Block. A plunger-like tool consisting of leather, rubber, or Teflon® discs layered between steel or wooden discs that may be solid or valved. Used to alternate flow from the well casing into the surrounding formation.

4.7 Transition Seal. An annular seal, with great expansion potential, placed between the filter pack and the annular seal to ensure a positive seal at the filter pack. The transitional seal prevents cement-based grout materials from entering the filter pack and typically consists of bentonite chips or pellets.

4.8 Tremie Pipe. A device, usually a small-diameter pipe with side discharge, that carries materials to the bottom of the borehole and allows for placement of materials upward from the bottom without introduction of appreciable air pockets and caved formation materials.

4.9 Well Casing. An impervious, durable, tubular, temporary or permanent well structure designed to:

- Prevent caving of the boring walls; and
- Provide access from the ground surface to some point in the subsurface for groundwater level measurement or sample collection.

4.10 Well Screen. A section of casing that has been machine slotted to allow for free movement of water into the well.

5.0 GENERAL

5.1 Monitoring wells can be installed by nearly every type of drilling method. Each method has a range of conditions where the method is most effective in dealing with the inherent hydrogeologic conditions and fulfilling the purpose of the well. The procedures presented in this SOP generally pertain to using hollow-stem auger, dual-tube percussion, air rotary casing hammer (ARCH), rotary or direct push drilling methods. In three of these methods, the well is constructed inside the hollow-stem augers or casing prior to their removal from the ground. Slight deviations are required for installing wells using other drilling techniques. For example, mud rotary, solid-stem auger and cable tool drilling methods generally require the incremental placement and withdrawal of drill stem in the well bore during drilling and well completion.

The objectives of monitoring well installation are:

5.1.1 To gain access to groundwater;

5.1.2 To provide a means for studying the hydrogeologic regime;

5.1.3 To identify the aquifers and potential pathways of contaminant migration;

5.1.4 To determine which contaminants are present in the groundwater and at what concentrations; and

5.1.5 To determine the aerial and vertical distribution of contaminants.

5.2 Ensuring a successful well installation requires that installation procedures are followed and properly documented. Essential components of a well include: well casing and well screen, filter pack, transition seal, annular seal, and surface completion.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** ensures that the well installation procedures comply with SOPs and enforcing agency requirements. Develops or directs the preparation of a detailed Field Sampling and Investigation Plan (FSIP) that includes the specifics of the well installation design, particularly the materials and procedures to be used.

6.2 The **Field Supervisor** ensures that the well installation procedures comply with all local, state, and federal regulatory agency requirements (in addition to the FSIP and this SOP), and that the field team members are trained and certified competent in the installation procedures. The Field Supervisor coordinates with the selected drilling company and ensures that they are a State of California licensed well driller.

6.3 The **Field Geologist** is knowledgeable of the requirements for well installations and maintains adequate records of the installation process and materials to document proper and defensible performance of well installation.

7.0 PROCEDURE

7.1 Wells will be designed, as outlined in the FSIP. The well construction details will be documented on the boring log and in the field notebook or applicable well construction form by the rig geologist. Upon completion of the well boring to the desired depth specified in the FSIP, the following procedures should be followed to ensure the proper installation and completion of the well.

7.2 Well Casing and Well Screen

7.2.1 Materials will be supplied and installed by the drilling subcontractor in accordance with specifications provided. The following is a general description of well construction material.

Wells will typically be constructed of PVC casing and screen. The well casing will be new and clean and all segments will be flush-threaded. The well screen slot size openings will be typically 0.010 or 0.020 inches. The well casing diameter will range from 1- to 2-inches for microwells to 4-inches for monitoring wells. PVC blank casing will be used from the well screen to the ground surface. The well screen interval will extend from about 5-feet above the water to about 10-feet below the water table.

If centralizers are required (wells deeper than about 60 feet), stainless steel centralizers will be used at specified intervals and will be fastened to the well casing and screen by means other than bonding agents.

7.2.2 Installation procedures include the following:

- All well casing and screen material shall be assembled, as designed, and installed with sufficient care to prevent damage to the sections and joints;
- Sections of well casing and screen must be connected by a mechanical method, such as flush threading, to prevent introducing contaminants into the well;
- If centralizing devices are necessary, they are mechanically fastened just below the bottom of the screened zone, just above the top of the screened zone, and at specified intervals in the well casing. This specific location centers the casing and screen in any open boreholes to prevent damage from inadequate support at installation and allows uniform installation of the filter pack and seals. No centralizers will be installed within the screen zone. Centralizers are generally not required on microwells;
- Prior to installing the section(s) of well screen into the well boring, a sediment cellar or end cap must be placed at the bottom of the well screen. The length of the cellar trap is typically 6 inches;
- During installation of the well casing, the drill depth must be periodically measured by a stainless steel weighted surveyors tape to ensure that the well boring remains clean of sloughed sidewall material;
- The casing must be suspended to provide 2- to 6-inches of filter pack below the end cap. Casing shall remain suspended until placement of filter pack and transition seal has been completed. Prefabricated

filter packs are available and may be used on small diameter temporary (microwells) wells; and

- Prior to the addition of the filter pack and annular seals, a cap shall be placed on top of the casing to avoid well materials from entering the well casing.

7.3 Sieve analysis will be conducted periodically where wells will be installed if the grain size distribution of the aquifer materials is not well documented. Sieve analysis will generally not be conducted for the installation of temporary wells (microwells). Filter pack materials must be poorly graded (well sorted) to ensure good permeability and hydraulic conductivity of the materials near the screen. The materials used should be chemically inert, well rounded, and slightly coarser than the surrounding formation. Using coarser material increases the effective well diameter.

Filter pack material shall be obtained from known clean sources and should be washed and properly packaged for handling, delivery, and storage.

The filter pack is designed based on the anticipated or tested grain size distribution in the screened formation and in conjunction with the size of well-screen openings. In general, the size of filter pack materials to be used will consist of either No. 3 Monterey Sand (8/20 mesh) for 0.02 slot size, or No. 2/12 (112/20 mesh) for 0.01 slot size.

7.3.1 Installation Procedures. The following procedures shall be used to optimize the installation of the filter pack and the quality of the well.

- The well boring should allow for a minimum of 2 inches of filter pack (total annular space 4 inches) around the well screen and between 2- and 6-inches of filter pack below the well end cap. Microwells will require less filter pack in the annular space as they are typically installed using small diameter direct push drilling techniques;

- The volume of the well annulus (i.e., filter pack required) must be pre-calculated and documented in the field logbook, and the volume of filter pack installed must be monitored and documented to ensure that the filter pack placement is complete. All discrepancies must be noted in the field logbook, explained and reported to the site manager/technical manager;

- Filter pack should be emplaced using a tremie pipe via gravity feed to prevent the possibility of bridging or segregation of the filter pack material through the water column. When using dual-tube or hollow stem auger drilling methods, the annulus between the well casing and drill stem may serve as the tremie pipe. Prefabricated filter packs may also be used. Installation of filter pack by slurry through a tremie pipe should only be undertaken when no other practical method exists, and then only using potable water;
- Filter pack must be placed in slowly to ensure that bridging does not occur;
- The depth to top of the filter pack must be continuously measured using a stainless steel surveyors measuring tape and noted to ensure uniform placement;
- Filter pack must be settled using a vented surge block for approximately 10 to 20 minutes prior to final top-off on wells with a diameter of 2-inches or greater;
- The depth of the top of the filter pack shall be verified to ensure proper placement at approximately 18 to 24 inches above the well screen; and
- Under no circumstances shall the filter pack extend into any aquifer other than the one to be monitored.

7.4 A transition seal is used to prevent cement-based sealing materials from infiltrating the filter pack. The permeability of the seal must generally be one to two orders of magnitude less than the surrounding formation. The seal must be chemically compatible with the anticipated contaminants and chemically inert so it does not offset the quality of groundwater samples.

Bentonite-based transition seals are normally used for the transition between the filter pack and annular seal. Fine-grained forms of bentonite, such as granules and powder, are usually employed for seals placed above the existing water level. Coarse forms of bentonite, such as pellets and chips, are often used when the seal is to be placed below the existing water level. A bentonite slurry can also be used for the transition seal and is often used for placement of the seal below the existing water level.

7.4.1 Installation procedures include the following:

- Two to three feet of transition seal material shall be placed on the top of the filter pack;
- The seal material must be emplaced using a tremie pipe to prevent the possibility of bridging. The annulus between the well casing and drill stem may serve as the tremie pipe;
- The depth to the seal shall be measured using a stainless steel surveyors measuring tape to ensure that the thickness of the transition seal meets the design requirements;
- For bentonite transition seals, sufficient time must be allowed for proper hydration (generally 15-30 minutes), before placement of the annular-seal;
- In general, 5 to 10 gallons of water is sufficient to hydrate a 2-3 foot transition seal if applied in 1 to 2 gallon increments; and
- The water added to the bentonite for hydration or to mix slurry shall be from a potable source. Document the volume added in the field logbook.

7.5 The annulus between the well casing and the wall of the well boring must be effectively sealed to prevent it from becoming a preferential pathway for the movement of pollution and contaminants.

This seal may be composed of pelletized, granular, or powdered bentonite, neat cement grout, and combinations of both.

Only Portland® Type II cement without accelerator additives may be used in a cement-bentonite mixture (grout). The grout will consist of approximately 5 to 7 gallons of water per 94 pound bag of cement and from 3 to 5 percent (by dry weight of cement) bentonite powder. This will help reduce shrinkage and control time of setting. Use of other grout mixture proportions must be discussed with the field supervisor. The cement bentonite grout must be free of lumps and have an average density of 13 to 15 pounds per gallon before pumping into the annular space.

7.5.1 The following tasks must be performed to achieve a positive seal in the annular space to the surface.

- The expected volume of each ingredient in the grout mixture shall be pre-calculated for each well and included in field notes;
- Only potable water from an approved source that is free of contaminants and pollutants shall be used;
- The bentonite must be thouroughly mixed with the water prior to the addition of the cement. This will allow for maximum hydration of the bentonite;
- Grout will be mixed prior to placement ensuring a thorough mixture without lumps;
- A minimum of 20 to 30 minutes, as appropriate, must have elapsed for the transition seal to set prior to grouting;
- The grout shall be emplaced through a tremie pipe inserted to within 5-feet of the transition seal. A side-discharge tremie pipe may be used for deeper transition seals (depths greater than 50 feet bgs) to lessen the possibility that the transition seal may be cavitated and grout introduced into the filter pack. The pipe must remain submerged in the sealing material during the entire time grout is being emplaced;
- For annular seals deeper than 60 feet, the drill stem should be withdrawn in increments during grouting to provide a positive seal to the well boring wall. A minimum of 2 feet of grout must be maintained in the drill stem as each section is removed. The drill stem may be completely withdrawn when the bottom of the drill stem reaches a depth of approximately 40 feet if the boring is not prone to collapsing;

- The grout shall not be placed in lifts exceeding 50 feet without documentation from the casing manufacturer of the temperature resistance; and

- Where the well depth is very deep (i.e., greater than 100 feet), a short segment of grout, at least 10 feet, may be placed first and allowed to set to prevent the casing from being buoyed upward.

7.6 Two types of surface completions are typical to monitoring well installations: 1) above-ground completion and, 2) flush-mounted completion. An above-ground completion is generally preferred, however, a flush-mounted completion may be specified or required in traffic areas. The purposes of surface completions and well protection are to prevent surface runoff from entering and infiltrating down the well annulus and to protect the well from accidental damage or vandalism. Upon completion of the well installation, the monitoring well shall be properly surveyed and the measurements documented.

7.6.1 Independent of the type of surface completion, there must be a concrete apron of neat cement or concrete around the well casing, filling the upper annular space. Depending on well site conditions, the following must be considered for placement of the concrete apron.

- A concrete apron is generally a separate seal emplaced on top of the annular seal. As the annular seal has highly impermeable characteristics, the concrete apron may be an extension of the annular seal; and

- Due to surface disturbances caused by drilling activities, the concrete apron will generally need to be extended a minimum of 1 feet out from the well casing on the surface, and have a thickness of 6 to 8 inches at the edges. The concrete surface will be smooth and finished so as to slope away from the well in all directions.

7.6.2 The following procedures shall be used for above-ground completions.

- Well casing shall extend 2 to 3 feet above the ground surface with a vented end plug or casing cap provided for each well;

- A protective casing will be installed around the well casing by placing the protective casing into the surface seal while still wet and uncured. Protective casing shall be positioned and installed in a plumb position;
- Protective casing must be set in the concrete apron and extend a minimum of 24 inches above the ground surface;
- Protective casing must be vented to allow for the escape of possible gas buildups and to allow the water levels to respond naturally to barometric pressure changes. Additionally, a small drain hole (approximately ¼") may be placed slightly above the concrete level to allow for draining of any trapped water from installation and sampling of the well;
- A locking cap shall be installed on the protective casing, ensuring adequate clearance between the top of the well casing and bottom of the locking cap;
- A concrete surface pad (generally 2-feet by 2-feet by 4-inches) shall be placed surrounding the well protective casing. The pad shall be sloped away from the protective casing; and
- Well protection posts may be placed around wells in any area where vehicular traffic may occur. In general, three or four 3-inch-diameter concrete-filled steel posts will be installed. Posts should be placed about two (2) feet below ground surface and should rise a minimum of four (4) feet above ground. The posts should not be placed in the concrete pad.

7.6.3. The following procedures shall be used for flush-mounted completions.

- Well casing must be cut off below grade (approximately 4- to 6-inches) leaving enough space for the placement of an end plug or casing cap at each well;
- A protective structure, such as a utility box assembly, will be installed around the well casing. The protective structure shall be centered in a 18- to 24-inch square concrete pad sloped away from the structure;

- For flush-mounted completions located in high traffic areas, completion will follow the procedures outlined above except a traffic-rated cement or steel vault will be used and cemented flush with the traffic surface; and

- For these flush-mounted completions, care should be used to ensure that the bond between the protective structure and cement surface seal and the protective structure and removable cover are watertight.

7.7 Monitoring wells shall be labeled as follows:

7.7.1 The words "Monitoring Well" and the well location number shall be clearly stamped or etched on the top of the cover of the protective casing for an above-ground well completion;

7.7.2 The words "Monitoring Well" shall be cast, clearly stamped or etched into vault cover for a flush-mount well completion. The well location number shall be clearly stamped or etched into the vault cover;

7.7.3 In addition, a metal plate or tag may be securely attached in an easily readable location inside the protective casing on an above-ground well completion and inside the vault on a flush-mount well completion with a minimum of the following information clearly stamped or etched into the metal.

- Well location number; and
- Well type (purpose)

7.8 All materials and procedures used during installation of the well shall be documented in field logbooks as detailed in SOP 1.0, Field Logbook.

8.0 RECORD KEEPING REQUIREMENTS

8.1 Well construction details shall be documented on the boring log and in the field logbook. Both of these documents will be placed in the project file at the completion of the project.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #22

FIELD MEASUREMENT OF pH

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to delineate protocols for measuring the pH of all types of aqueous solutions, including drinking water, saline water, industrial and domestic wastes.

2.0 SCOPE

2.1 This SOP applies to all project team personnel and subcontractors tasked with measuring the pH of liquids and soils.

3.0 REFERENCES

3.1 Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske. 1985. Practical Guide For Ground Water Sampling. Illinois State Water Survey, Champagne, IL.

3.2 USEPA. 1977. Procedures Manual For Ground Water Monitoring At Solid Waste Disposal Facilities. US EPA. Manual SW-611, Contact No. 68-01-3210.

3.3 EPA TEGD. 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document. USEPA Office Of Solid Waste And Emergency Response. OSWER-9550.1.

3.4 GARSKE, E.E., and M.R. Schock. 1986. An Inexpensive Flow-Through Cell and Measurement System For Monitoring Selected Chemical Parameters In Ground Water. Ground Water Monitoring Review, Summer, pp.79-84.

3.5 Test Methods For Evaluating Solid Waste, SW 846. Physical and Chemical Methods, Third Edition, Update III, December 1996, Methods 9040 and 9045.

4.0 DEFINITIONS

4.1 The pH scale is a measure of hydrogen ion concentration. Each unit is equivalent to a factor of ten in hydrogen ion concentration. This makes the pH scale logarithmic. Strongly acidic samples have low pH values and strongly basic samples have high pH values.

4.2 Solubility is the capability of a substance to be dissolved or liquefied into a solution, and/or is the amount of a substance that can be dissolved in a given liquid (solvent) under specified conditions.

4.3 Well Purging is performed to fill the well with representative groundwater by removing static well water. Monitoring wells should be purged until field chemistry parameters such as pH and specific conductance have stabilized to assure that the water in the well casing has reached equilibrium with water stored in the aquifer.

4.4 Preservation refers to temperature controls and/or pH adjustment procedures performed to prevent or slow the loss of target analytes through precipitation, volatilization, decomposition, or biodegradation.

4.5 Onsite Measurement refers to measurements in which samples have received no treatment or preservatives and very little time elapses between their removal from the aquifer and their presentation to portable electronic instrumentation sensors.

5.0 GENERAL

5.1 pH is one of the primary groundwater and/or soil quality parameters that must be measured in the field to avoid errors caused by contamination and/or equilibrium change when a sample is transported away from the sample site for analysis.

There are several reliable and accurate electronic sensors available for the field measurement of this parameter. These range from digital and analog pH meters to in-line flow cells that are sealed from the atmosphere that, in addition to pH, also measure electrical conductivity, temperature, oxidation reduction potential, and dissolved oxygen. Any meter used to measure pH should be strongly constructed and suitable for rugged field use, have easily rechargeable and/or replaceable batteries, and provide accurate but easily conducted calibration protocol.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure that the procedure for field measurement of pH is included in the project planning documents.

6.2 The **Site Manager/Technical Manager** shall ensure that the sample team members are trained and competent in the field measurement of pH procedure and data documentation.

6.3 The **Field Supervisor** shall ensure that each step in the field measurement is followed and that the data are recorded properly.

7.0 PROCEDURE

7.1 Meters with flow through in-line cells capable of measuring several sampling parameters are preferred for field investigation use. In addition to the pH meter, the following materials ae required for equipment calibration:

- Buffer solutions (pH 4, 7, and 10);
- Clean containers (glass or plastic); and
- Distilled or deionized water in wash bottle.

7.2 Calibration

7.2.1 Calibration shall be performed daily following the manufacturers guidelines using standard buffer solutions of 4.0, 7.0, and 10.0 pH units. Care must be taken to clean the electrodes with deionized water between measurements so that carryover does not occur. At a minimum, pH calibration shall be two point.

7.2.2 Buffer solutions used for onsite calibration shall be labeled with source, value, date of make-up from parent stock, and expiration date of parent stock. On-site solutions shall be replaced daily from parent stock.

7.2.3 When the pH of a sample is over pH 12 or under pH 2, pH meters become unreliable and require special calibration solutions. Also, electrodes dipped into such solutions take a long time to recover and become operable in the usual range. It is best to use pH paper if such extreme pH conditions are suspected.

7.3 **Decontaminate following SOP 11.0.**

7.4 **pH Measurement - Flow Through In-Line Cell**

7.4.1 Calibrate the instrument in accordance with the manufacturers instructions.

7.4.2 Connect the flow through in-line cell to an appropriate clean purging/sampling pump.

7.4.3 Place the purging/sampling pump into the groundwater well as required and below the water table level.

7.4.4 Operate the purging/sampling pump and the flow through in-line cell according to the manufacturers instructions. As the water flows through the sample chamber, the system simultaneously measures the temperature, pH, electrical conductivity, and other optional sampling parameters.

7.4.5 Read the pH value from the display and record per the manufacturers instructions.

7.5 **pH Measurement - Digital or Analog pH Tester**

7.5.1 Calibrate the instrument in accordance with the manufacturers instructions.

7.5.2 Rinse the inside of the sample cup with some of the liquid to be measured. (This is especially important if samples with a wide range of conductivity or pH are to be measured).

7.5.3 Fill the sample cup at least 2/3 full with the liquid to be measured.

7.5.4 Place the pH electrode in the non-metallic sample cup. Wait approximately 1 to 2 minutes for the display to stabilize.

7.5.5 Read the pH of the sample from the display and record the results.

7.6 pH Measurement - Soil pH Meters (Soil/Liquid and Soil Direct)

Soil pH measurements require mixing a specific amount of soil sample with ASTM type II reagent grade water and immersing a pH electrode into the resulting slurry.

7.6.1 Calibrate the instrument in accordance with the manufacturer's instructions.

7.6.2 Immerse the pH electrode into the soil/water slurry solution and stir gently.

7.6.3 Read the display for the pH reading and record the results.

Another method of measuring soil pH is to use a soil meter that has been embedded directly into the soil.

7.6.4 Calibrate the instrument in accordance with the manufacturer's instructions.

7.6.5 Insert the pointed end of the pH electrode vertically into the soil and pack the soil firmly around the electrode.

7.6.6 Wait approximately 3 minutes for the indicating needle to stabilize.

7.6.7 Read the pH value and record the result.

8.0 RECORDKEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 The sampling team leader, or designee, is responsible for keeping up-to-date field records that document all sampling activities. The attached audit checklist should be completed daily. Refer to Field Logbook - SOP 1.0 for additional data documentation guidelines.

9.0 ATTACHMENTS

Attachment A Audit Checklist - Field Measurement of pH

ATTACHMENT A

AUDIT CHECKLIST - FIELD MEASUREMENT OF pH

Signature of Auditor ____________________ Date of Audit ____________

Project Manager ____________________ Project No. ____________

Field Coordinator ____

Client Representative(s) ____

Project Location ____

Type of Investigation ____

1. Does the pH meter have the following capability?

   Measure temp Yes____ No____

   Measure specific conductance Yes____ No____

   Temperature compensator corrected to 25º C Yes____ No____

   Digital readout Yes____ No____

   Analog readout Yes____ No____

Yes ___ No ___ N/A ___ 2. Have the manufacturers instructions been consulted for operation, calibration and measurement techniques for that particular meter?

Yes ___ No ___ N/A ___ 3. Have pH 4, 7 and 10 buffer solutions been used to calibrate the meter?

Yes ___ No ___ N/A ___ 4. Was the meter calibrated as follows?

- At the beginning of the days sampling event
- After 4 hours of prolonged shutdown
- When readings become suspect
- At the end of the days sampling event

Yes ___ No ___ N/A ___ 5. Were the calibration results and time of calibration documented in the field logbook?

Yes ___ No ___ N/A ___ 6. Was the sample temperature at the time of pH measurement taken and recorded in the field logbook?

Yes ___ No ___ N/A ___ 7. Were the measurement conditions documented in the field logbook?

Yes ___ No ___ N/A ___ 8. Has the pH electrode been stored in the proper solution between measurements?

Yes ___ No ___ N/A ___ 9. Was the pH electrode properly decontaminated between measurements?

Yes ___ No ___ N/A ___ 10. Was the instrument stored in the shade whenever possible?

Yes ___ No ___ N/A ___ 11. Was the instrument decontaminated, labeled clean, secured, and properly stored for usage at the next site?

BENICIA SOP #23

FIELD MEASUREMENT OF TEMPERATURE

1.0 PURPOSE

1.1 This standard operating procedure (SOP) describes the procedures to measure temperature readings in environmental samples.

2.0 SCOPE

2.1 This SOP applies to all filed sampling activities where temperature measurements are required.

3.0 REFERENCES

3.1 Brown and Caldwell Consultants. 1991. Hazardous Materials Field Procedures Manual, September.

4.0 DEFINITIONS

Not applicable

5.0 GENERAL

5.1 Temperature readings are used in the calculation of various forms of alkalinity, in studies of saturation and stability with respect to calcium carbonate, in the calculation of salinity, and in general laboratory operations.

6.0 RESPOSIBILITIES

6.1 The **Field Supervisor** is responsible for the supervision of daily operations as related to temperature measurement.

7.0 PROCEDURES

7.1 Normally, temperature measurements are made with a calibrated thermocouple. At a minimum, the thermocouple should have a scale marked for every .1 degree Celsius, with markings etched on the capillary glass.

7.2 The thermocouple should have a minimal thermal capacity to permit rapid equilibration. Periodically, check the thermocouple against a precision thermocouple certified by the National Institute of Standard (NIST) that is used with its certificate and correction chart.

7.3 For field operations, use a thermocouple having a metal case to prevent breakage.

7.4 Measure temperature downhole or in a small flowthrough cell, if possible. Record measurements in the field logbook periodically throughout the time of pumping.

7.5 Calibrate any temperature measurement devices with a NIST certified thermocouple before field use. Make readings with the thermocouple immersed in water long enough to permit complete equilibration. Report results to the nearest 0.1 or 1.0 degree celsius depending on need.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 Field logbook

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #24

SPECIFIC CONDUCTANCE MEASUREMENTS

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to delineate protocols for measuring the specific conductance of any aqueous solution, including drinking water, saline water, industrial and domestic wastes

2.0 SCOPE

2.1 This SOP applies to all field sampling activities where specific conductance measurements are required.

3.0 REFERENCES

3.1 USEPA. 1983. Methods for Chemical Analysis of Water and Wastes, March, 1983.

4.0 DEFINITIONS

4.1 Conductivity is the ability of an aqueous solution to pass an electrical current. The current is primarily carried by dissolved inorganic ions such as chlorides, nitrates, sulfates, along with cations such as sodium, calcium, magnesium and others. Organic compounds do not carry current and therefore have almost no conductivity.

5.0 GENERAL

5.1 Specific conductance is a widely used indicator of groundwater quality. It is a simple indicator of change within a system and provides useful information to laboratory analysts performing other measurements on the sample.

5.2 Specific conductance is slightly dependant on temperature, and directly related to salinity.

5.3 Be certain there is no air in the cell before taking a reading.

5.4 If conductivity meter does not have integral temperature compensation, use a thermometer to determine temperature of the sample.

6.0 RESPONSIBILITIES

6.1 The **Field Supervisor** is responsible for the supervision of daily operations as related to specific conductance.

7.0 PROCEDURES

7.1 A conductivity meter will be used with integral temperature compensation – accuracy ± 2% at 25° C (77°F). The meter shall be calibrated at the beginning of each day using the following procedure:

7.1.1 Thoroughly rinse the probe with appropriate conductivity reference solution, and zero the meter if appropriate.

7.1.2 Measure the specific conductance of fresh appropriate conductivity reference solution record it in the field notebook, and adjust the calibration knob until the meter reads properly.

7.1.3 Rinse probe with deionized water.

7.1.4 Measure the specific conductance of deionized water and record in the field logbook. If Specific conductivity of deionized water is not 0 (±2%) recalibrate instrument.

7.2 Operation of the specific conductivity meter as follows:

7.2.1 Thoroughly rinse the probe and sample beaker with sample water, and measure the temperature of the sample water.

7.2.2 If Celsius temperature is not obtained directly, convert Fahrenheit temperature readings to Celsius using C=5/9 (F-32).

7.2.3 Place the probe in the sample beaker with sufficient sample to completely submerge the probe. Swirl the probe to remove any air bubble trapped in the probe.

7.2.4 Select the highest multiplier scale on the meter and turn the instrument on. Progressively use lower multiplier scales until a mid-scale deflection is obtained.

7.2.5 If appropriate, check probe accuracy by pressing cell test button. If value change is > 10% check probe.

7.2.6 Record the temperature and conductivity values.

7.2.7 Specific conductivity values are corrected for temperature using:

$$K_{25°C} = \frac{K\ measured}{1 + 0.0191\ (t\text{-}25)}$$

where:

K = conductivity in µmhos

t = temperature, °C Follow decontamination procedures in SOP

7.3 The following steps will be taken to properly maintain the conductivity meter:

7.3.1 Check the batteries each time the instrument is used.

7.3.2 Inspect the probe on a daily basis for damage or loss of platinum black plating from the electrode. If the platinum is damaged, alert the Field Team Leader and arrange to get a new cell.

7.3.3 Follow manufacturers specifications regarding storage of probe between uses.

8.0 RECORD KEEPING REQUIREMENTS

Not applicable

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #25

FIELD MEASUREMENT OF WATER LEVELS

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to describe the procedures and equipment used to accurately determine static water level and total depth in a groundwater monitoring well, pumping well, or piezometer.

2.0 SCOPE

2.1 The water level data obtained are used to determine the hydraulic gradient in an aquifer and changes in water levels over time. The level and total depth are used to calculate the volume of standing water in the well. This information is used to estimate the amount of water to be evacuated from a well before sample collection and to establish when wells are fully recharged following purging.

3.0 REFERENCES

3.1 Driscoll, F.G. 1986. Groundwater and Wells, Johnson Filtration Systems, Inc., St. Paul, MN, , 1089 pp.

3.2 U.S. Department of the Interior (USDI). 1981. Groundwater Manual, A Water Resource Technical Publication, Water and Power Resources Services, U.S. Government Printing Office, Denver, CO, 480 pp.

4.0 DEFINITIONS

Not applicable

5.0 GENERAL

5.1 This procedure requires the use of an electronic water level that employs a battery-powered probe assembly attached to a cable marked in 0.01-foot increments. When the probe makes contact with the water surface, an electrical impulse is transmitted in the cable to activate an audible alarm.

5.2 The water level indicator is equipped with a sensitivity adjustment switch that enables the operator to distinguish between actual and false readings caused by the presence of conductive, immiscible components on top of the groundwater.

The manufacturer's operating manual should be consulted for instructions on use of the sensitivity adjustment.

5.3 The measurements of static water level and total depth must be taken at an established reference point, generally at the top of the casing at the surveyor's mark. The mark should be permanent, e.g., a notch or mark on the top of the casing.

5.4 If the surveyor's point is not marked at the time of the water level reading, the north side of the casing should be marked and used.

5.5 All equipment shall be decontaminated before and after introduction of the equipment to the well following procedures in SOP 11.0. However, when measuring water levels in multiple wells, the following decontamination steps may be incorporated for use.

5.5.1 The indicator probe and 5 feet beyond the portion of the cable used will be decontaminated by washing with a solution of laboratory grade detergent and potable water. The probe and cable will then be rinsed with potable water, followed by a final deionized (DI) water rinse. This decontamination procedure may only be used for wells that do not contain free product or extreme contamination.

5.6 If it is not possible to measure the total depth of a well in which pumping equipment is installed, the as-built construction plans will be used.

5.7 For multiple or cluster wells, the same operator using the same sounder will measure depth to water in each well.

5.8 For site-wide soundings, all sounders to be used shall be calibrated against each other by measuring depth to groundwater in one well and noting any differences in depths so that corrections can be made.

5.9 During groundwater sampling events, the water level indicator shall be decontaminated by washing the protion of the cable housed in the well and probe with laboratory grade detergent, followed by a potable water rinse, and a DI water rinse. This decontamination procedure may only be used for wells that do not contain free product or extreme contamination.

6.0 RESPONSIBILITIES

6.1 The **Field Supervisor** shall ensure that specific SOPs for level and depth measurement and decontamination are followed.

7.0 PROCEDURES

7.1 A water level indicator with audible alarm and a cable marked in 0.01-foot increments will be used. The point on the probe that triggers the alarm corresponds to the zero point. Stainless-steel plumb may be needed to add weight to the water level indicator for detecting the bottom of the well. The additional weight may be necessary beyond 80 feet due to the buoyancy of the cable.

7.1.1 The static water level will be measured each time a well is to be sampled. This must be done before any fluids are withdrawn and before any purging or sampling equipment enters a well. If a weight is to be attached to the water level probe to measure the depth of the well, it should be attached before the water level is taken.

7.1.2 If the well is sealed with an airtight cap, allow time for equilibration of pressures after the cap is removed before water level measurement. To verify equilibration, water level readings should be taken about three minutes apart to determine if water level is static. The water level is considered static if three consecutive readings are within 0.01 foot.

7.1.3 With the water level indicator switched on, slowly lower the probe until it contacts the water surface as indicated by audible alarm. Raise the probe out of the water until the alarm turns off. Repeat raising and lowering the probe until the precise level is determined. Record the reading on the cable at the established reference point to the nearest 0.01 foot.

7.1.4 To measure the total depth of the well, slowly lower the water level indicator (with plumb attached if necessary) until the cable goes slack. Raise and lower the probe until the precise location of the bottom is determined. Record the reading on the cable at the established reference point to the nearest 0.01 foot. The measurement must be adjusted based on the actual location of the zero depth on the probe. Record data required in Section 7.1.5.

7.1.5 The following minimum information shall be recorded in the field logbook:

- Date and time of measurements;
- Equipment used and serial number;
- Measured water levels;
- Measured total depth;
- Reference point for measurements if other than the established reference point;
- Water level measurement offset, if appropriate;
- Water level adjusted for zero, if appropriate; and
- Total depth adjusted for zero.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 Field logbook

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #26

PHOTOGRAPH/VIDEO DOCUMENTATION

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to ensure that representative photographic evidence of site conditions, field technician observations, site work procedures, and completed project work is documented for uses including, but not limited to, project orientation and documentation, training, community and public relations, and business development purposes.

2.0 SCOPE

2.1 This procedure applies to all project team personnel and subcontractors who work on projects that require documentation of the project's site conditions, progress, and ongoing work processes. The photographs or videotape produced may also include project-related items of significant and noteworthy interest, such as coverage of major project events, innovative field techniques or procedures, that should be documented.

3.0 REFERENCES

Not applicable

4.0 DEFINITIONS

4.1 A Camera is any photographic apparatus that includes a lightproof box fitted with a lens through the aperture of which the image of an object is recorded on light-sensitive film.

4.2 The Film is the light-sensitive material on which a photographic image is recorded.

4.3 A Video Recorder is the camera used to record a videotape.

4.4 Videotape is the material on which a television image, with associated sound, is recorded.

4.5 A video cassette is a recording on videotape contained in a cassette.

4.6 Print refers to the positive photographic image transferred to paper or a similar surface, usually from a photographic negative. Print sizes are usually the standard 8x10 inch, 3x5 inch, or 4x6 inch sizes.

4.7 Slides or transparencies are photographic images on transparent film for projection on a screen.

4.8 Model release form is a form used to obtain permission to photograph or videotape a person.

4.9 Clearances refer to all permissions granted, usually by the client, to photograph or videotape anything under the client's control or ownership.

4.10 Community Relations refers to the interactive process where both decision makers and community members relay and receive information. Under the "community relations" umbrella of activities, information is presented in an unbiased, objective manner that encourages two-way communication with the public.

4.11 Public Relations are those activities that seek to persuade, encourage, or influence opinion, or sell an idea or product.

5.0 GENERAL

5.1 Photographs and video recordings provide the most accurate documentation of the field technicians observations. They can be significant to the field team during inspections, informal meetings, and hearings. They can also be important in the training and project orientation of employees, vital in any community relations activities performed on behalf of the client, and, in some cases, useful in corporate business development and public relations efforts.

5.2 Photographs should be taken with a camera-lens system having a perspective similar to that afforded by the naked eye. Telephoto or wide-angle shots cannot be used in enforcement proceedings, although these types of photographs can provide more drama to the field action and are ideal for community and public relations purposes. These "dramatic" photographs are usually taken by subcontractors hired by the company's community relations or public relations staff.

5.3 It is also generally preferred that the still or video camera have an automatic date and/or time captioning capability. Generally, the date and/or time caption is automatically printed on the bottom right corner of the photographic print or video image. Such a captioning capability aids in later labeling and identifying the photographs or videotapes.

6.0 RESPONSIBILITIES

6.1 The **Project Manager**, or his or her designated representative, will accompany the subcontractor at the job site and will direct and assist the subcontractor as necessary.

6.2 The **Site Manager** is responsible for designating a member of the field team to act as photographer or videographer. The Site Manager is responsible for ensuring that all documentation forms and their corresponding materials are placed in the field logbook(s).

6.3 In some cases, a **subcontractor** (i.e., a professional photographer or videographer) will be hired to take pictures. The subcontractor's responsibilities and authority will be enumerated in his or her contract, but, in general, the field team will be expected to cooperate with and take direction from the subcontractor.

6.4 It may be necessary to have the **Site Safety and Health Officer (SSHO)** accompany the photographer to the job site to ensure that all health and safety regulations are being followed. The photographs taken can become documentation of health and safety violations as well as good health and safety practices.

6.4.1 It is mandatory that the photographer (a project team employee, or a subcontractor) be well versed and trained in all field health and safety practices. This includes obtaining adequate briefing as to the hazards that should concern both the photographer and the subjects of the photographic shoot at the project site. The photographer, a member of the field team, is responsible for following all health and safety regulations that govern the project site or the type of work involved at the site. This includes arriving at the site wearing all necessary personal protective equipment (PPE).

7.0 PROCEDURE

7.1 Photographs and videotapes must be documented to be a valid representation of the recorded event. Therefore, for each photograph taken or videotape recorded, several items shall be stated in the field logbook. These items may include:

7.1.1 Name of project and project number;

7.1.2 Sequential number of the photograph on the film roll and the roll number;

7.1.3 Film type and film speed (ASA number) or videotape speed;

7.1.4 Name of photographer;

7.1.5 Date and time photographs/videotapes taken, and site location; and

7.1.6 General direction faced and description of the subject.

7.2 The photographic prints (and their associated negatives), slides, or videotapes will also be placed in the project file with the logbook(s).

7.3 Permission to bring a camera onto a job site or within a client's facility in order to photograph any proceedings in which the project team and its subcontractors are engaged must be obtained well in advance of the event. Because the project activity and/or location may be of a highly sensitive or confidential nature, this requirement is of utmost importance.

In general, a phone call or letter sent noting the reason for the request and the use of the photographs to the client's project manager or representative is adequate to request permission. Documentation that permission has been granted should be kept in the field file.

The client may also request the undeveloped rolls of film after the photograph or videotaping session. This is the client's privilege. Even if the client's job site and the activity to be photographed is nonsensitive, not confidential, or even clearly within the view of the general public, confidentiality agreements with the client often places additional restrictions as to the taking and usage of photographs or videotapes at project sites.

The Project Manager and Site Manager should be kept informed during these procedures to obtain clearances. In some cases, the Project Manager or Site

Manager may have to contact the client directly to obtain permission to photograph or videotape an activity at the client's project site or facility.

7.4 Written releases may be required from the client to use a specific photograph, a series or group of photographs, or a videotaped recording. This release not only reassures the client as to the ultimate use of the photograph, it also protects the contractor from liability should the client later object to the printing or other use of the photograph(s) or videotape(s).

7.5 If a subcontracted employee is contracted to photograph or videotape a project site or project activity, he or she automatically become a temporary member of the project team and must follow all of the procedures as would apply to full-time employees.

The subcontracted photographer or videographer should also be prepared to surrender all photographic negatives and prints and/or videotape to the contractor and/or the client. Because many photographers normally retain copyright control of their photographs, it is necessary that the terms of compensation and the need to relinquish all rights to the work be clearly understood and negotiated in advance.

8.0 RECORDKEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 Copies of project photographs or videotape must be retained in the project file. Any documentation relating to photographic or videotape logs or documents granting permission to photograph or videotape should be placed in the project file.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #27

DRILLING

1.0 PURPOSE

1.1 This standard operating procedure (SOP) establishes the procedures and methods for drilling. These guidelines will help ensure consistency and quality in drilling of exploratory boreholes.

2.0 SCOPE AND APPLICABILITY

2.1 This procedure applies to the drilling of boreholes for the purpose of collecting soil and soil gas samples, for the installation of vapor extraction, groundwater monitoring wells, small diameter temporary wells, and for the collection of *in situ* groundwater samples. These procedures shall be implemented by all project team personnel and subcontractors involved with drilling boreholes.

3.0 REFERENCES

3.1 "Method for Penetration Test and Split-Barrel Sampling of Soils", ASTM Method D1586.

4.0 DEFINITIONS

Not Applicable

5.0 GENERAL

This procedure applies to the drilling of boreholes for the purpose of collecting soil, soil gas, or groundwater samples. These guidelines will help ensure consistency and quality in drilling exploratory boreholes.

5.1 Equipment and supplies that may be needed to implement this SOP include a backhoe, drill rig, short-masted drill rig (for limited access) or direct-push rig; solid-stem augers or drive samplers; a slide-hammer and sampling tube; a Hydropunch® (or equivalent) sampler; sample collection supplies; a concrete corer; decontamination equipment; and other materials as noted from the reference SOPs.

5.2 During pre-drilling and drilling activities, proper Health and Safety Procedures will be followed at all times. Proper ventilation will be provided for drilling in limited access areas or within buildings. Doors, windows and vents will be kept open at all times, if possible. Exhaust and ventilation fans and ventilation tubing will be used to exhaust engine emissions and to provide fresh air to the inside of the enclosed space at all times during drilling. Explosive vapor and oxygen monitoring will be conducted along with scheduled monitoring. Should the oxygen level fall below 20 percent, drilling will be stopped until proper ventilation returns oxygen levels to at least 20 percent.

5.3 Proper QA/QC procedures will be followed at all times as called for in this and the referenced documents. Proper decontamination of drilling and sampling equipment per the requirements of SOP No. 11.0, will be done to mitigate cross-contamination. Equipment blanks will be collected to insure the quality of analytical samples collected. Other QA/QC procedures as deemed necessary by the Quality Assurance Officer will be implemented as needed.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure overall compliance with these procedures.

6.2 The **Field Supervisor** and **Field Geologist** shall assign qualified personnel and train personnel on these procedures.

7.0 PROCEDURES

Drilling will be conducted using the following guidelines.

7.1 The selection of locations and depths for wells and subsurface soil and groundwater sample sites will be a cooperative effort between the contractor, the USACE, and the appropriate federal and state regulatory agencies, as applicable.

7.1.1 Criteria for the selection of well and subsurface sample locations will be based on specific objectives of each drilling or sampling effort. However, the locations will generally depend on the following:

- Suspected presence or absence of contamination in the vadose and saturated zones;
- Current or historical groundwater gradients and flow directions;
- The need to further characterize the geologic conditions;

- Proximity to past waste disposal sites;
- Proximity to receptors such as water supply wells;
- Favorable access for drilling equipment (see Section 7.4, for limited access drilling);
- Presence of overhead power or telephone lines; and
- Location of underground structures such as sewer lines, power lines, and water lines.

7.1.2 Final selection of a site will depend on securing all necessary rights-of-entry, clearances, and permits. Prior to drilling, electrical cable and pipe-locator instruments will be used in conjunction with underground utility maps (if available) to determine if underground utilities are present at the drilling location. In addition, geophysical methods may be used for underground utility location.

7.1.3 Prior to drilling, a review of available hydrogeologic data, analytical data, and an examination of contaminant distribution maps (if available) will be conducted.

7.2 Prior to initiation of drilling activities at any site, the Field Supervisor will verify that all necessary permits and clearances have been granted for each soil boring or well. Only then will drilling equipment be mobilized to a drilling site. The Field Supervisor will be responsible for coordination of obtaining all permits and clearances necessary for drilling wells and soil borings.

7.2.1 The Field Supervisor will be present, or will be contacted, each time the drill rig is moved to a soil boring or well site. If necessary (drilling in a neighborhood or inside of a building), the drill site shall be covered with polyethylene sheeting, prior to positioning the drill rig, to protect the immediate area from possible contact with contaminated drill cuttings and to facilitate cleanup efforts. In addition, where containment of fluid is a concern (i.e., drilling fluids, groundwater, sampler decontamination areas), lumber or PVC pipe shall be used to berm the edges of plastic sheeting for the affected area covered with the sheeting. The berm must be of sufficient height to prevent any fluid generated from operations from running off the sheeting.

7.2.2 The Field Supervisor or Field Geologist shall direct positioning of the rig such that the center of the borehole is within 2 feet of the predetermined well location (identified by a stake or paint mark). Such accuracy is necessary to avoid underground utilities, possible violation of property lines, rights-of-entry, or other agreements that have been negotiated with property owners.

7.2.3 Prior to drilling a borehole, the drill string (casing, auger, drill pipe, bit, etc.) and rear portions of the drill rig shall be cleaned by a high pressure, hot water wash. Upon completion of decontamination and mobilization of drilling equipment to the drill site, exclusion and support zones as referenced in the HSP shall be identified and marked prior to commencement of drilling operations. All health and safety equipment (tables, water, eye wash station, etc.) will also be set up at this time and shall be located in an upwind direction. The Field Geologist or rig technician shall be responsible for this effort

7.2.4 Boreholes will be drilled and completed using one of the methods described in Section 7.6. Subsurface soil samples will be collected at soil boring locations utilizing a sampler that is appropriate for the drilling method and that meets sample collection objectives. Samples will be removed from the sampler, described lithologically in accordance with SOP 3.0 in the boring logs, and prepared for submission to the analytical laboratory (if applicable). All drilling residuals (i.e., soil cuttings, drilling mud, and decontamination fluids) will be disposed in a manner consistent with the Investigation Derived Waste Plan. Other investigation-derived materials (to include personal protective equipment [PPE], decontamination materials, etc.) will be contained and placed in a secure area onsite prior to final disposal. Personnel handling samples will wear approved hand protection.

7.3 The following drilling requirements will be maintained during drilling activities:

7.3.1 All drilling and well installations will conform to state and local regulations. The Field Supervisor will coordinate all permits, applications, site clearances, and any other necessary documents required by state and local authorities;

7.3.2 The location of all borings will be approved by USACE personnel before drilling commences;

7.3.3 Each borehole location will be cleared by hand augering the entire diameter of the borehole;

7.3.4 The rig shall be cleaned and decontaminated according to the specification in SOP 11.0;

7.3.5 The rig shall not leak any fluids that may enter the borehole or contaminate equipment that is placed in the hole. The use of rags to absorb leaking fluids is unacceptable. Any leaks, which may contaminate the borehole or equipment will be fixed by the drilling subcontractor immediately. All work will stop until leak is fixed;

7.3.6 The only acceptable drilling fluids are air, water, and drilling mud (bentonite). The air shall be filtered to remove organic vapors, the water shall be from a potable source, and the drilling mud shall be approved by the Field Supervisor and Project Manager;

7.3.7 When air is used, the effectiveness of the filter shall be checked at least once per day. Air passing through the downstream end of the air line shall be monitored with an organic vapor monitor (e.g., photoionization detector or equivalent). If organic vapors are detected, their source (filter, contaminated line, etc.) shall be decontaminated or replaced;

7.3.8 Lubricants shall not introduce contaminants. Unless Teflon® tape is the only lubricant used, the contractor shall obtain written authorization from the Field Supervisor for any lubricant used on equipment that enters the hole; and

7.3.9 When installing wells through more than one hydrostragraphic zone, the contractor shall take measures to prevent cross-contamination of the zones.

7.4 Each drilling location will be cleared by hand augering to approximately 5 feet, and reaming to the diameter of the drill stem to be used.

7.4.1 In the event of refusal, defined as the physical inability of the team to advance the boring in a reasonable amount of time, due to a "hardpan" layer, borehole clearance will be considered adequate. If buried utilities are thought to be present, the Field Supervisor will direct the relocation of the boring and the process will be repeated. For undeveloped areas, where there is little likelihood of encountering buried utilities, the above clearing procedure may be waived if the Field Supervisor, Field Geologist, and Health and Safety Officer concur. This discussion and concurrence must be documented in the field logbook. The above procedure will ensure that each boring has a complete lithologic log and that the 5-foot bgs sample is not excluded from analysis.

7.5 Boreholes to be drilled should meet the following requirements:

7.5.1 The borehole diameter should be adequate to allow proper installation of well and collection of representative soil and/or groundwater samples. If monitoring wells are installed, the borehole diameter shall meet all applicable state and local well regulations.

7.5.2 Formation samples for lithologic description may be obtained continuously in specified borings at 5-foot intervals, or as specified in the FSIP. If organic vapors are suspected, samples shall be monitored with an OVM (e.g., Hnu, OVA). If specified in the FSIP, rock cores shall be stored in standard core boxes and missing sections of core boxes and missing sections of core shall be replaced with spacers.

7.6 Borings will be drilled for the purpose of identifying the lithology, collection of subsurface soil, soil gas, and groundwater samples, and for well construction. All drilling, lithologic identification and sampling, and other related activities will be supervised by a geologist, hydrogeologist, or geotechnical engineer. Borings will be monitored for organic vapors and explosive gases (if applicable to site conditions) during drilling using a PID, or FID in conjunction with an explosimeter as specified in the HSP. Readings will be taken at the top of the boring and immediately before sampling. The readings will be recorded on a field form, or in the field logbook. Each soil sample will be screened with the PID or FID, and the readings will be recorded on the boring logs, or in the field logbook.

7.6.1 All borings shall be completed and abandoned, in accordance with applicable state and local regulations and guidelines.

7.6.2 The choice of drilling methods listed below is influenced by many factors including:

- Anticipated boring depth and diameter;
- Anticipated lithology;
- Type of sampling required;
- Type of well construction required (if applicable); and
- Space limitations.

7.6.3 The following is a brief description of the drilling methods that may be employed including:

- Hollow Stem Auger (HSA);
- Direct push;
- Air Rotary Casing Hammer;
- Sonication;
- Dual Tube Percussion; and
- Mud Rotary.

7.7 The hollow stem auger (HSA) drilling method employs a hollow helical steel drill that is rotated to advance the boring and cuttings to the surface. The flights for the HSA are welded onto steel pipe and a cutter head is attached to the lead (bottom) auger to cut the hole. During drilling, a center bit or continuous core-split barrel is inserted into the hollow area of the cutter head to prevent drill cuttings from entering the hollow portion of the auger. Generally, the center bit or barrel is flush with, or extends no more than ½ foot below, the cutter head. The center bit or barrel is connected through the auger flights by small diameter drill rods attached to the top head drive unit of the drill rig. The center bit or barrel may also be seated into the bottom of drill string and attached to a rig winch cable.

The top head drive is powered by a truck-mounted engine that mechanically rotates the entire flight of augers. The hollow opening allows the insertion of sampling tools (i.e., split-spoon sampler, or continuous soil coring device) and well completion materials while the augers are in place supporting the borehole. The HSA technique may be used when collection of analytical samples in the vadose zone is planned or when a single groundwater monitor well is to be completed at the water table and a geophysical log is not required.

7.8 This method of borehole drilling is used at locations where consolidated, semi-consolidated, or gravels exist, and the formation cannot be effectively drilled using other methods. Drilling mud is not required for this drilling method. The method is cost-effective for producing borings for well construction when continuous core and geophysical logs are not required. This method is not suitable for sampling soil for volatile organics.

The air rotary casing hammer (ARCH) drilling method uses a drilling bit attached to the lower end of a rotating drill pipe that is placed within a nonrotating outer drive casing. The drill bit advances the boring simultaneously as the nonrotating drive casing is driven into the ground. Air is forced under pressure downward through the drilling rods and bit and back to the ground surface through the annulus between the drive casing and the smaller rotating drill rod. The returning air continuously moves cuttings and groundwater from the area of the drill bit to the surface where they are discharged into a cyclonic separator. The separator separates the air from the formation cuttings to facilitate sampling and containment for drill cuttings. The outer casing is driven downward by repeated blows of a percussion hammer mounted on the drilling rig. The drive casing keeps the borehole open and reduces the flow of groundwater into the boring. Because of the reduction of groundwater flow into the boring, the potential for cross contamination between waterbearing zones is diminished. The drive casing is pulled out of the boring with hydraulic jacks during well construction.

Groundwater brought to the surface during drilling is collected in a tank and transported from the drill site. The rate of penetration using this drilling method depends on the type of subsurface formation, size of the hole, type of bit, size of the drive casing, and the amount of pressurized air forced down the drill pipe. When using this method for drilling in the saturated zone, the drill bit shall never be advanced more than one foot deeper than the bottom edge of the drive casing.

7.9 Direct push drilling technology is used when small diameter relatively shallow sampling is required. Direct push is a cost effective method of installing small diameter temporary wells (microwells). Direct push drilling generates little or no drill cuttings.

The direct push method uses a small diameter drive shoe and continuous rod that is mechanically pushed (similar to a jack hammer) and rotated into the subsurface. A continuous core of soil is collected in the sample sleeve (usually plastic) as the drill stem is advanced. Continuous cores are retrieved at a typical interval of 3 feet. Soil samples can be lithologically logged or packaged directly for chemical analysis.

Groundwater samples may be collected with the drill stem installed in the borehole using an *in-situ* groundwater sampling device. A temporary small diameter (1- to 2-inch) casing can be installed in the borehole for groundwater sample collection. The annular space of the temporary well casing may be sealed to allow collection of future water samples.

The primary advantages of using direct push drilling technology are that it can be used in relatively limited spaces and it does not generate large volumes of cuttings. The main limitation is that it is typically limited to depths of about 40 feet below ground surface.

7.10 This method of drilling may be used at locations where continuous core samples must be collected from the vadose zone. The method is effective for the rapid production of boring sufficient for soil, soil gas, and Hydropunch® groundwater sampling with no additional cuttings generation.

The sonication (sonic) method employs a hydraulically activated drill head that imparts high frequency sinusoidal wave vibrations normal to the ground surface through the drill string. Operational frequency is between 70 and 150 Hertz (Hz). At optimum frequencies (between 120 and 150 Hz) the drill bit produces approximately 30,000 lbs of upward/downward force; the vibration produced breaks the cohesive bonds in soil and rock. A split-spoon sampler or a solid drive point can be latched into the bottom of the drill string to collect core samples or drill to a desired sampling depth. Soil is either forced into the split-spoon sampler or is forced aside as the drill string is advanced. In hardpan or bedrock the bit is rotated to cut through the material.

7.11 Similar to the air rotary casing hammer method, this method is effective for the construction of monitoring wells when continuous core and geophysical logs are not required. The potential for contaminant migration in borehole liquids is diminished by this method.

The dual tube percussion method utilizes a small diameter drill pipe and a larger diameter drive casing with high pressure air as the circulating medium. Air is forced down the annular space between the inner drill pipe and outer drive casing and cuttings are returned to the surface through the inner drill pipe. The drill pipe is advanced by repeated blows of an aboveground percussion hammer. Impact from the hammer is applied to the outer drive casing only, therefore very little space exists between the outer drive casing and surrounding formation (soil). The drive casing keeps the borehole open and as in the air rotary casing drive method, diminishes the potential for cross contamination of water-bearing zones. The cuttings are discharged into a cyclonic separator which separates the air from the formation cutting to facilitate sampling and containment of drill cuttings. Groundwater produced during drilling is collected in a tank and transported from the drill site. The rate of penetration depends on the type of subsurface formation, size of hole, size of the drive casing, and the volume of air forced down the drill pipe.

7.12 The mud rotary drilling method employs a bit that attaches to the lower end of a drill pipe and advances the boring as the drill pipe is rotated. In direct circulation rotary drilling, a drilling mud is pumped down through the drill pipe and out through the ports or jets in the drill bit. The mud consists of a mixture of water and bentonite powder. The mud then flows upward in the annular space between the hole and drill pipe carrying the cuttings in suspension to the surface. At the surface the mud is channeled across a shaker to a settling pit or pits where most of the remaining cuttings drop out. The mud is then recirculated down the borehole. The mud functions are to transport the cuttings, support and stabilize the borehole, seal the borehole to prevent fluid loss, allow the cuttings to be separated at the surface, cool and clean the bit, and lubricate the bit. The mud weight and viscosity will be monitored and recorded at the start of drilling each day and at intervals during the drilling unless mud conditions (e.g., increased or decreased viscosity, etc.) or drilling conditions (e.g., lost circulation) change rapidly in the borehole. Normal drilling conditions should maintain a sand content of 4 percent or less, viscosities of 35 to 40 seconds/quart, and mud weights of 9 to 9.5 pounds/gallon. Under abnormal conditions, such as lost circulation, caving, or increasing solids content, the FTM should be consulted. The rate of penetration depends on the type of subsurface formation, size of hole, type of bit, mud weight and viscosity, and weight on the bit. The use of the direct rotary method allows resistivity and spontaneous potential geophysical surveys to be conducted. The subsequent geophysical survey assists in the drilling and construction of other wells in a cluster.

7.13 During drilling operations where cuttings are produced, soil cuttings and drilling muds will be monitored for organic vapors, placed in steel (plastic liners may be used), 55-gallon drums or other approved containment, and transferred to roll-off bins or staging area for temporary storage, if necessary. Results of field PID readings and chemical analyses of soil samples collected in borings will be used to determine the proper management of the cuttings. Chemical analyses of drilling mud samples will be used to determine their management. Each drum will be labeled with site name, boring name, client responsible for work, and person and phone number for contact.

The handling, transportation, storage, treatment, and disposal of drill cuttings and drilling muds will be as described in the Investigation Derived Waste Plan.

7.14 It may be necessary from time to time to collect soil samples within buildings or other enclosed spaces with limited access. When required to do so, the following procedures will apply:

7.14.1 A backhoe with a power take-off or a short masted drill rig will be used to drill boreholes with solid-stem augers or a direct-push rig will be used to advance a probe and sampling shoe. Solid stem augers or probe-type samplers will be used to limit the amount of soil cuttings generated during drilling. Drilling and sampling using this method will be limited to a maximum depth of approximately 40 feet below ground surface. Both soil and soil gas samples may be collected using these methods;

7.14.2 If required, a concrete corer will be used to cut an access hole in concrete flooring prior to drilling. Overhead obstructions and hazards will be identified and moved if possible. If not possible to move overhead hazards, the borehole location will be moved to a different location;

7.14.3 During pre-drilling and drilling activities, proper Health and Safety Procedures will be followed at all times, including proper ventilation. Doors, windows and vents will be kept open at all times, if possible. Exhaust and ventilation fans and ventilation tubing will be used to exhaust engine emissions and to provide fresh air to the inside of the enclosed space at all times during drilling. Explosive vapor and oxygen monitoring will be conducted along with scheduled monitoring of organic vapors as per SOP 5.0. Should the oxygen level reach 20 percent, drilling will be stopped until proper ventilation returns oxygen levels to at least 20 percent; and

7.14.4 Soil and, if applicable, groundwater sampling will be conducted using the sampling procedures and equipment that is appropriate for the desired analysis.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 The use of properly filled out and signed field log forms and field logbook is required. No other forms are required. Copies of all log forms and the field logbook will be placed in the project file at the completion of the project.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #28

CONE PENETROMETER DRILLING AND SAMPLING PROCEDURES

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to delineate protocols for cone penetrometer drilling and sampling.

2.0 SCOPE AND APPLICABILITY

2.1 This procedure applies to all project team personnel and subcontractors who conduct field investigations and collect and/or handle environmental samples.

3.0 REFERENCES

3.1 Forsgren Associates/Brown and Caldwell. 1998. *Chemical Data Quality Management Plan, February.*

4.0 DEFINITIONS

ASTM – American Society for Testing and Materials

CPT – Cone Penetrometer Testing

5.0 GENERAL

5.1 CPT is a rapid and cost-effective method to characterize subsurface conditions in unconsolidated sediments to depths of 100 feet. The testing procedure is also described in ASTM Method D3441. Depending upon the site and the data quality objectives (DQOs), CPT is often conducted in conjunction with soil, soil gas, and/or ground water sampling.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure that the CPT procedures used will adhere to this SOP.

6.2 The **Field Supervisor** is responsible for the supervision of daily operation as related to CPT operations.

6.3 The **Rig Geologist** is responsible for following the procedures outlined in this SOP.

7.0 EQUIPMENT AND PROCEDURES

7.1 **Equipment.** The cone penetrometer assembly and support equipment is typically mounted on a dedicated CPT truck (e.g., a 25-ton rig). The CPT assembly consists of a small diameter, instrumented probe with attached sounding rods, electronic cables, a hydraulic ram, and a computerized data acquisition and display system. The hydraulic ram propels the probe through the soil at a constant rate of four feet per minute and can generate up to 25 tons of force on the CPT probe. The CPT probe measures the soil's resistance to penetration as it driven into the ground and transmits these data to the data acquisition system for storage and retrieval. Real-time measurements of tip and sleeve friction, conductivity, resistivity, and pore pressure can be obtained depending upon the configuration of the CPT. The sounding rods can also be modified to collect soil and ground water samples.

A HydroPunch® I or HydroPunch® II, or equivalent sampler, may be used to collect groundwater samples using the CPT rig.

A Geoprobe® soil vapor sampling system may be used to collect soil gas samples at designated locations.

7.2 **Procedures.** Specific procedures for conducting CPT will depend upon the DQOs, the sampling location(s), and the capabilities of the particular CPT system. The locations, depths, DQOs, and sampling requirements of the CPT program are outlined in the field sampling plan (FSP). The FSP must be read and thoroughly understood by field personnel before beginning field work. CPT includes the following steps:

7.2.1 Calibration. Prior to testing, CPT should be conducted adjacent to an existing monitoring well or soil borings in the vicinity of the test site that was logged for lithology and other physical conditions. These data are collected to calibrate the penetrometer sensor response compared with the borehole log. The CPT calibration step provides useful data for interpreting the CPT data collected at the test site; the calibration well/borehole is chosen based on the following criteria:

- Representativeness of the soil type at the test site;

- Total depth of the well; and

- Quality of the lithologic log.

7.2.2 Data Collection. Data collection procedures are designed to meet the objectives and reporting requirements specified in the test plan.

7.2.3 Soil Gas Sampling. The Geoprobe® Soil Vapor Sampling System may be used to collect soil gas samples. A disposable point is pushed to the desired sampling depths, and the rod is retracted to expose a port between the point and the rod. A vacuum pump draws the soil gas sample via ¼-inch tubing connected to the sample point push rod adapter. The soil gas sample can be collected in a sample container (e.g., Tedlar® bag or canister) or can be taken directly from the sample tubing using a syringe and hypodermic needle.

7.2.4 Soil Sampling. Soil sampling is accomplished using a piston-type sampler with stainless steel or brass collection tubes. The sampler is pushed in a closed position to the desired sampling depth. The inner portion of the sampler is retracted and the sampler is then pushed into the soil.

The piston sampler works best in soils with some cohesion. If multiple depth interval soil sampling is to be performed, a wireline piston-type sampler can be used. This system greatly increases soil sampling production, because the rods are not "tripped" in and out of the hole for each sample.

7.2.5 Pore Pressure Data. Maintenance of the pore pressure element saturation is critical for accurate pore pressure data. The pore pressure filters are saturated under a vacuum in a glycerin bath prior to CPT sounding. The glycerin is more viscous than water and maintains better saturation while the cone is pushed through unsaturated soil.

7.2.6 Additional Resistivity Data. CONETEC, Inc. has developed a resistivity module located immediately behind the standard piezocone. The soil resistivity measurement assists in accurately defining the capillary fringe, the groundwater table, and the soil lithology. Resistivity measurements are controlled largely by pore fluid. In cases where contaminants with resistive properties different than water are present, the resistivity cone can be used to delineate contaminant plumes without ground water sampling.

7.2.7 Groundwater Sampling. Ground water sampling is accomplished using the QED HydroPunch® I or II. QED has downsized the HydroPunch® system from 2" to 1.75" in diameter. This HydroPunch® may thus be pushed with much less load and can be pushed to greater depth for projects where silt, clay, or hardpan may exist. This may be a substantial advantage where deeper groundwater is encountered. Furthermore, this system can reenter the same hole for multiple-depth groundwater sampling.

7.2.8 Decontamination. Downhole equipment is decontaminated by passing the sounding rods and probe tip through a rod-washing chamber at the bottom of the hydraulic ram assembly as they are retrieved. High-pressure steam cleans soil and ground water from the exterior of the downhole equipment. Rubber seals at the top and bottom of the rod washing chamber prevent decontamination water from leaking to the ground surface and remove soil from the downhole equipment. Decontamination water is collected and stored for appropriate disposal.

Decontamination of ground water and soil sampling tools is generally performed in the triple sinks on the CPT rigs. Large water reservoirs and a water heater provide hot running water for decontamination. The triple sinks will be filled with the appropriate washes as outlined in the specifications.

Push rod decontamination is performed with an automated steam cleaning collar. The collar consists of rubber wipers and three jet nozzles where high pressure steam is injected as the rods are pulled into the truck. Both the inside and outside of the ground water sampling rods are steam cleaned using the steam cleaner/high pressure washer from the support rig once the rods are pulled from the ground. Steam cleaning the inside of the groundwater sampling rod is generally performed, because the bailer may have spilled inside the rod while being retrieved.

7.2.9 Sealing of the CPT Probe Boring. Following CPT completion, the borehole is sealed using standard techniques. Specifically, a neat cement/bentonite grout slurry is prepared. Grout is pumped through the sounding rods after each section of sounding rod is removed from the boring. Approximately 0.75 gallons of grout are generally required to seal ten feet of penetrometer boring. Grout is continuously placed from total depth to the ground surface. All CPT locations are checked within 24 hours to observe if grout has settled; additional grout is added to the CPT hole, if necessary. The location is then periodically checked until the grout remains flush with the ground surface.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

Not applicable

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #29

TRENCHING

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to set procedures for trenching and determining the boundaries of landfills and burnsites.

2.0 SCOPE AND APPLICABILITY

2.1 This procedure applies to all project team personnel and subcontractors who participate in excavation and sampling of landfills and burnsites.

3.0 REFERENCES

Not applicable

4.0 DEFINITIONS

Shoring. Support structure installed to inhibit soil erosion and movement during excavation activities.

IDHL (immediately dangerous to life and health). Typically, IDLH environments are atmospheres with acute chemical exposure hazards that require supplied breathing air. These environments may also result from explosive atmospheres and oxygen-deficient atmospheres.

5.0 GENERAL

5.1 A survey of the area to be trenched will be conducted with geophysical instruments to determine locations of any underground facilities and/or buried drums (refer to Geophysical Testing SOP 18.0).

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure that the trenching procedures used will adhere to this SOP.

6.2 The **Field Supervisor** is responsible for the supervision of daily operation as related to trenching activities.

6.3 The **Field Geologist** is responsible for following the procedures outlined in this SOP.

7.0 EQUIPMENT AND PROCEDURE

7.1 Equipment

7.1.1 Excavator. An excavator such as Caterpillar (CAT) Model 235 or equivalent will be use to excavate pest pits/trenches which exceed 20' depth. For excavation with a depth of 20' or less, a CAT 225 or equivalent will be used. Excavators shall be equipped with 24" buckets and enclosed operator cabs. Operator cabs shall be equipped with self-contained breathing apparatus (SCBA) for IDLH environments. For excavation in wet or soggy areas, excavators shall be equipped with low ground pressure (LGP) tracks to reduce sinking.

7.1.2 Shoring. If test pits/trenches show signs of failure, sloughing, caving, or other distress, the hazardous waste operations and emergency response standard in 29 Code of Federal Regulations (CFR) 1910.120 Occupational Safety and Health Administration (OSHA) shall be implemented. The excavation will thus remain open and safe during data gathering and/or visual assessment activities. Shoring shall be installed at properly spaced intervals as determined by soil lithology, excavation depth, vegetarian cover, proximity to structures or underground utilities, and subsurface obstacles. Determination of the need for shoring shall be made on a case-by-case basis in the field by the site engineer/geologist and/or designated site health and safety officer overseeing excavation activities. No personnel shall enter trenched deeper than four feet.

7.1.3 Backfill and Compaction. Backfill and compaction of test pits/trenches shall be accompanied using an excavator or suitably sized front-end loader. Placement of the backfill shall be conducted in appropriately-sized lifts to ensure proper compaction. Where required by the field sampling plan (FSP), compaction to 95% shall be accompanied with a hydraulically-controlled vibratory plate compactor connected to an excavator. A nuclear density gauge in conjunction with soil results from ASTM-D-698 shall determine compaction effort to ensure all areas receive adequate surface pressure during placement and compaction. Where 95% compaction is not required by the FSP, visual inspection shall ensure sufficient pressure is applied during soil placement and compaction.

7.1.4 A 35 mm camera (minimum) or Downhole Video Camera/Video Tapes. Optional when not required in the FSP, a battery-operated (rechargeable) 8 mm video camera equipped with a spotlight will record lithologic information (fill versus native materials) to the base of the trench. The cameral will weather resistant, mounted within a steel frame, and attached to two 10-foot lengths of 1-inch polyvinyl chloride (PVC) pipe. A color video monitor will be used to view the subsurface lithology either as recording proceeds or immediately after recording to aid decision-making in the field.

7.1.5 Steel Measuring Tape. A 1-inch-wide by 25-foot-long steel measuring tape will be used to determine trench depth and length during excavation and to measure video camera depth during recording. Markings of depth will also be made on the PVC pipe to estimate camera depth at the surface.

7.1.6 Rectangular Gridded Paper or Logbook. A rectangular gridded logbook or sheets of bound grid paper will be utilized to create plain view and cross sections of the subsurface geology as trenching proceeds.

7.1.7 Real-Time Instruments. Direct reading instruments, such as organic vapor meters (OVMs), Draëger® tubes, explosivity meters, etc., will be used to perform health and safety monitoring as required in the Forsgren Associates/Brown and Caldwell Health and Safety Program Manual or Site Specific Field Site Investigation Plans (FSIPs).

7.2 **Procedures.** The following procedures will be used to determine site boundaries through trenching:

7.2.1 Prior to the start of trenching activities, mark the traverse that will be followed using 3-foot-long wooden stakes at 5- to 10-foot intervals. Also prior to excavation, all underground utility to process lines that may be encountered will have their locations determined and marked and the proper digging permit signed. If necessary, several exploratory "pot holes" may be dug to ensure the trench will intercept the pit or landfill.

7.2.2 Collect a soil sample for physical property analysis by ASTM-D-698 to support compaction tests, if required by USACE.

7.2.3 Using a hydraulic excavator equipped with a 24-inch bucket, trench to approximately 5 feet along and a 10- to 15-foot length. Record concentrations of VOCs with a photoionization detector (PID), or equivalent.

7.2.4 Determine the presence of VOCs using a PID or equivalent at the surface and along the length of the trench. If digging in landfills, determine the presence of methane gas and the potential for explosion using a flame ionization detector (FID or equivalent, and a combustible gas indicator (CGI) at the surface and along the length of the trench. PID, CGI, and FID readings that raise health and safety concerns will be identified in each site specific FSIP.

7.2.5 Map native and fill material observed at the surface and in the trench; measure distances and depths and record in the field logbook or on grid paper.

7.2.6 Take instrument readings and map the subsurface at 5-foot depth increments along the 10- to 15-foot segment of the trench. The trench shall be dug to: a) the depth identified in the FSP; b) the depth where the base of the original landfill, pit, or preexisting pond or creek is identified in the subsurface through visual observations/instrument readings; or c) the top of a perched water zone. Under no circumstances will trenching activities be allowed to continue deeper than the top of an identified perched water zone or first water.

7.2.7 At depth intervals of 10 feet, begin recording the subsurface geology and any evidence indicating the surface of a disposal or burn pit, landfill, or pond. Video or still (35 mm) camera recordings should be made at approximately 20-foot intervals along the trench and used as a depth marker/reference during video taping.

7.2.8 As each segment of the trench reached total depth, advance to the next segment of the trench and repeat steps 3 through 7. Avoid having the excavator straddle the trench as this may collapse the trench walls.

7.2.9 Backfill excavated materials and compact the material in the trench.

7.2.10 Continue steps 2 through 8 as required to meet the objectives of the FSIP.

When field personnel are not present, the trench will be taped off and protected with barrier tape and night-flashing safety barriers according to requirements established by OSHA or USACE, whichever is more stringent.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 Documentation for each excavation shall be the responsibility of the field geologist. At a minimum, the following information will be documented in detail:

- Name and location of trenching site.
- Date and time excavation started and stopped.
- Approximate surface elevation.
- Total depth of the excavation.
- Dimensions of the pit.
- General geologic descriptions and descriptions of any foreign material, visual staining, or odors. If buried drums are encountered, see the SOP for excavation and sampling of buried drums.
- Types of instruments for monitoring.
- Organic vapor, methane, and oxygen concentrations.
- Depth to perched water (if encountered).
- Photographs.
- Cross section through the trench (from video or visual mapping) indicating depth of fill/native material.
- Plan view of trench and nearest undisturbed soil.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #30

METHANOL PRESERVATION FOR VOLATILE ORGANIC COMPOUNDS IN SOILS

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to describe preparation, sample collection, and handling procedures for methanol preservation of samples for volatile organic compound (VOC) analysis.

2.0 SCOPE AND APPLICABILITY

2.1 This procedure applies to soil samples collected in stainless steel or brass sleeves to be analyzed for mid to high VOC levels. This procedure is applicable to both field and off-site laboratory analysis.

3.0 REFERENCES

Not applicable

4.0 DEFINITIONS

ASTM American Society for Testing and Materials

FSP Field sampling plan

g gram

MeOH Methanol

µL Microliter

mL milliliter

QAPP Quality Assurance Project Plan

QC Quality control

5.0 GENERAL

5.1 This procedure is performed if designated in the site specific Field Site Investigation Plan (FSIP). Preservation in methanol can reduce the potential for VOC loss during sample shipment, handling, and storage. Repeated analysis may be performed without further significant VOC loss. Low levels of VOCs may not be detectable with this sample preservation method because of sample dilution and associated elevated detection limits.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure that the methanol preservation procedures used will adhere to this SOP.

6.2 The **Field Supervisor** is responsible for the supervision of daily operation as related to methanol preservation activities.

6.3 The **Field Geologist** is responsible for following the procedures outlined in this SOP.

7.0 EQUIPMENT AND PROCEDURES

7.1 Equipment

7.1.1 Laboratory/Preparation Equipment

- 500-mL amber glass jars with Teflon®–lined lids
- Surrogate spike solutions
- µL pipette
- Pesticide grade MeOH
- 250-mL graduated cylinder
- Scale capable of weighing to the nearest 1 g
- Data sheets

7.1.2 Field Sampling Equipment

- Decontaminated brass or stainless steel sleeves, 2.5 inch diameter, 1.5 inches long
- Coolers with ice
- Prepared sample bottles

7.2 **Preparation/Pre-Sampling Operations.** Arrange for the laboratory to provide the prepared sample bottles for the sampling effort. Provide a schedule and project point of contact to ensure sufficient communication exists between the field and laboratory so that changes or problems can be quickly addressed. Request a sufficient number of sample bottles to collect ambient and trip blanks as designated in the FSP and/or field instructions. To minimize the potential for cross contamination, prepared bottles should be shipped so that they are not stored on site for more than two days before use.

In the laboratory, sample bottle preparation should be performed in a "clean" area where potential ambient VOC contamination is minimized.

7.3 Laboratory Sample Container Preparation

7.3.1 Measure 250 mL of pesticide-grade MeOH into each sample bottle with a graduated cylinder or volumetric flask (accuracy within 5 mL is needed).

7.3.2 Add 625 µL of each surrogate compound to each sample bottle with a calibrated pipette. Cap the bottle tightly and gently mix the contents. The following surrogates should be added for the designated analytical method:

- SW8010 – bromochlormethane, 2-bromo-1chloropropane, and 1,4-dichlorobutane.
- SW8020 – 1-bromo-4-fluorobenzenem and 1,1,1-trifluorotoluene.
- SW8240 – 1,2 dichloroethane-d4, toluene-d8, and 1-bromo-4-fluorobenzene. A an alternative, use 1 µL per mL of MeOH of the Purgeable Surregates 650 Standard Mix A supplied by Cambridge Isotope Laboratories or equivalent. This mixture contains each of the three surrogate compounds at a concentration of 2,500 µL/mL in MeOH.

7.3.3 Invert the bottle and check for leakage; if leakage is evident, tighten lid and check again. If leakage still occurs, replace the lid or the entire sample bottle.

7.3.4 Weigh the bottle to the nearest gram and record on a log sheet. Figure 1 shows the information that must be recorded for each sample bottle.

7.3.5 Place a label on the bottle and fill the bottle ID, weight, method(s) for which surrogates have been added, and the date prepared.

7.3.6 Store the bottles in the refrigerator until shipment to the field; ship the bottles in coolers with ice to maintain temperature at 4ºC. Prepared bottles should not be stored for more than seven days before shipment.

7.4 **Sample Collection Procedures.** In the field, the sample bottles should be kept on ice in coolers until use. Exposure to ambient air should be minimized to avoid contamination from ambient conditions (VOCs are easily absorbed into MeOH).

7.4.1 Initiate field sampling data sheet and other documentation forms required as described in the applicable SOP and Section 6.0 of the QAPP.

7.4.2 Collect samples for VOC analysis using decontaminated brass or stainless steel sleeves inside a split-spoon sampler. Standard 2.5 inch diameter, 1.5 inch long sleeves should be used. This size sleeve will generally contain between 150 and 200 grams of soil, and minimizes the potential for VOC loss by reducing the exposed soil surface area.

Note: if sleeves of different sizes are used, they should hold approximately the same weight/volume of soil. The MeOH volume can be adjusted to maintain the approximate ratio of 1.25 to 1.7 mL of MeOH to each gram of soil. Verify that the different size sleeve will fit into the sample bottles before arranging for laboratory preparation.

7.4.3 Open a prepared bottle sample. Without removing the soil sample from the sleeve, gently place the sleeve and sample into the sample bottle. This step should be done quickly, without splashing or agitating the MeOH, or with as little agitation as possible. Immediately wipe any soil from the lip of the bottle and replace the lid. Do not mix or otherwise disturb the sample.

7.4.4 Label the sample bottle and store on ice or refrigerate until shipment and analysis. Complete sample documentation forms as required.

7.4.5 If shipment is required, follow applicable requirements for shipping hazardous/flammable liquids.

7.4.6 Collect ambient and trip blanks at the frequencies designated in the FSP or field instructions. Refer to Section 4.5 of this SOP for QC samples.

7.4.7 Collect an adjacent soil sample for moisture determination, or identify an adjacent field sample collected for other analyses be used to calculate dry weight concentrations for the MeOH preserved sample. Document on field data sheets.

7.5 Post-Sampling and Analytical Procedures

7.5.1 After the sample has been logged in at the laboratory, wipe off any moisture or condensation.

7.5.2 Weigh the bottle to the neatest gram and record the total weight on a data sheet (the same one used to record the initial weight or another laboratory tracking form).

7.5.3 Analyze the sample as requested. The analytical procedure will generally follow that for mid- to high-level samples that require methanol extraction of the soil sample.

7.5.4 After analysis is completed, remove the sleeve from the sample bottle, clean, and weigh the sleeve to the nearest gram. Subtract this from the total weight to obtain the sample weight.

7.5.5 Calculate the sample concentrations in dry weight using the sample weight and percent moisture result from the designated sample. Calculate surrogate recovery. Report the sample results as requested.

7.6 **Quality Control Samples**. Methanol can easily absorb ambient VOCs, resulting in false positive analytical results. Therefore, both ambient and trip blanks should be collected to identify potential sources of VOC contamination. The frequency and collection for these QC samples are described below.

7.6.1 <u>Ambient blanks</u>. To identify ambient contamination sources or problems, ambient blanks should be collected from each sampling location on each day of sampling. Ambient blanks consist of MeOH plus any surrogates in the same proportions as for a sample. Ambient blanks are prepared and collected by opening a prepared sample bottle near the sample collection location for approximately the length of time required to collect a sample. Replace the lid and submit along with field samples for analysis. Complete documentation as required for other samples.

7.6.2 Trip blanks. One trip blank should be included with every shipment of MeOH preserved samples. Trip blanks consist of prepared sample bottles that are handled and shipped unopened with the field samples.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

Not applicable

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #31

FIELD CLASSIFICATION AND DESCRIPTION OF ROCKS

1.0 PURPOSE

1.1 The purpose of the standard operating procedure (SOP) is to provide project team employees with the proper method for field classification and description of rocks for entry into borehole logs.

2.0 SCOPE AND APPLICABILITY

2.1 Procedures defined herein are followed by project team employees for entry of classification and description of rocks into borehole logs.

3.0 REFERENCES

3.1 Compton, Robert R., *Geology in the Field*, John Wiley & Sons, New York, 1985.

3.2 Osiecki, P. and Dirth, L., RG Exam Study Guide, 1996.

4.0 DEFINITIONS

Not applicable

5.0 GENERAL

5.1 Rock identification is based on minerals and textures.

5.2 Drilling in rock will be slow and core recovery may consist of pulverized chips. The proper drilling technique is necessary for adequate recovery and accurate rock identification.

6.0 RESPONSIBILITIES

6.1 Each **Project Manager** shall ensure that the rock classification and description procedures used conform to the guidelines in this SOP.

6.2 The **Field Supervisor** is responsible for reviewing lithologic logs for accuracy and completeness prior to releasing them to the project manager for review.

6.3 The **Rig Geologist** is responsible for following the rock classification and description procedures in this SOP, and for accurately and completely representing the lithology encountered in the field.

7.0 PROCEDURES

7.1 Sedimentary Rock Classification. Sedimentary rocks result from two processes (and combinations thereof):

- Consolidation of loose sediments that have accumulated in layers, forming clastic rocks.
- Precipitation from solution to form a chemical rock. Included in this category are rocks directly or indirectly formed by biological processes.

7.1.1 Chemical Rocks. Chemical rocks have been classified according to chemical composition, depositional texture, and depositional environment.

Common chemical rocks are limestone, dolomite, evaporites (gypsum, anhydrite, halite, etc.) phosphate rocks (apatite), manganese nodules, ironstones (limonite, siderite, and chlorite silicates), coal, pyrite, chert, and diatomite, and some cherts have a biogenic component to their formation.

7.1.2 Clastic Rocks. Clastic rocks have been classified different ways. They may be classified according to the size of particles, sorting, and distribution of particles, or chemical content of silica, feldspar, and calcite.

7.1.2.1 *Grain Size.* In the most commonly used classification system, the size of the particles determines the general rock name. For example, sand-sized particles for sandstones; pebbles form conglomerates, and so on. The rack names are shown in Table 1 along with their component particle sizes. The divisions in the classification are based upon the Modified Wentworth scale used to measure grain size.

Table 1. Grain Size Scale (Modified Wentworth Scale)

Diameter (in)	Particle	Sediment	Rock
< 0.0002	Clay	Mud	Claystone, mudstone, shale
0.0002 to 0.002	Silt		Siltstone
0.002 to 0.08	Sand	Sand	Sandstone
0.08 to 2.5	Pebble	Gravel	Conglomerate (rounded) Breccia (angular)
2.5 to 11.8	Cobble		
> 11.8	Boulder		

Conglomerates and breccias have adjectives such as *clast-supported and matrix supported*. *Clast-supported* means that he clasts are sorted well enough so that the large clasts touch, and *matrix-supported* is not.

A well-sorted sandstone is called an arenite. A poorly sorted sandstone with a matrix of silt and clay is called a wacke. A sandstone with more than 25% feldspar is an arkose. And, if lithic fragments or iron and magnesium minerals and feldspar are present along with quartz sand and silt, the rock is called a graywacke.

7.1.2.2 *Sorting.* Sedimentary rock names are further characterized by the sorting the particles have undergone. The distribution of grain sizes reflects the type of transport a sediment has experienced and the depositional environment. A well-sorted (or poorly graded) sediment has two or three sizes present. A poorly sorted (or well-graded) sediment has a wide range of grain sizes present.

7.1.2.3 *Cementation.* Cementing substances have usually been referred to by adjectives such as calcareous, dolomitic, and siliceous; however, these terms might also imply accessory detrital materials, so that the unambiguous terms calcite-cemented, dolomite-cemented, and quartz-cemented are recommended.

7.2 Igneous Rock Classification. Classification of igneous rocks is based upon the mineral content of the rock. Minerals upon which the classification is based are feldspar, quartz (or feldspathoids), and mafic minerals such as biotite, hornblende, pyroxene, and olivine. Of these minerals, identifying feldspar is the key to classification.

7.2.1 The IUGS Subcommission on the Systematics of Igneous Rocks attempted to create a universal classification of igneous rocks. The committee's recommendations for plutonic and volcanic rocks are shown in Tables 2 and 3, respectively. A rock is classified by determining it composition relative to the percentage of alkali feldspar, plagioclase, and quartz (or feldspathoid).

7.3 Metamorphic Rock Classification. In this binomial system for naming metamorphic rocks, the main rock name is based on the texture of the rock, and the principal or more significant minerals are added as modifying nouns, as in biotite-quartz schist or andalusite-cordierite hornfels. The names are meant to be applied on a descriptive basis; a schistose rock, for example, should not be called a hornfels just because it is found in a contact aureole.

7.3.1 Textures.

- Schistose – grains platy or elongate and oriented parallel or subparallel. *Foliated* (lepidoblasitc) of fabric is planar, *lineated* (nematoblastic) if linear.
- Granobalstic – grains approximately equidimensional; platy and linear grains oriented randomly or so subordinate that foliation is not developed.
- Hornfelsic – grains irregular and interincluded but generally microscopic; recognized in field by unusual toughness, ring to hammer blow, and hackly fracture at all angles. Under hand lens, freshly broken surfaces show a sugary coating that will not rub off (formed by rending of interlocking grains).
- Semischistose (gneissic) – platy or linear grains subparallel but so subordinate or so unevenly distributed that rock has only a crude folliation; especially common in metamorphosed granular rocks, such as sandstones and igneous rocks.
- Cataclastic – clastic textures resulting from breaking and grinding with little if any recrystallization; characterized by angular, lensoid, or rounded fragments (porphyroclasts) in a fine-grained and commonly streaked or layered

Table 2
Modal Classification of Plutonic Igneous Rocks

Modal Values	Classification
Q > 60	Not igneous
Q = 20-60, P <10	Alkali feldspar granite
Q = 20-60, P = 10-65	Granite
Q = 20-60, P = 65-90	Granodiorite
Q = 20-60, P >90	Tonalite
Q = 5-20, P <10	Alkali feldspar quartz syenite
Q = 5-20, P = 10-35	Quartz syenite
Q = 5-20, P = 35-65	Quartz monzonite
Q = 5-20, P = 65-90	Quartz monzodiorite (An < 50) Quartz monzogabbro (An > 50) Quartz anorthosite (M < 10)
Q = 5-20, P >90	Quartz diorite (An < 50) Quartz gabbro (An > 50) Quartz anorthosite (M < 10)
Q = 0-5, P <10	Alkali feldspar syentie
Q = 0-5, P = 10-35	Syenite
Q = 0-5, P = 35-65	Monzonite
Q = 0-5, P = 65-90	Monzodiorite (An < 50) Monzogabbro (An > 50) Anorthosite (M < 10)
Q = 0-5, P >90	Diorite (An < 50) Gabbro (An > 50) Anorthosite (M < 10)
F = 0-10, P <10	Foid-bearing alkali feldspar quartz syenite
F = 0-10, P = 10-35	Foid-bearing syenite
F = 0-10, P = 35-65	Foid-bearing monzonite
F = 0-10, P = 65-90	Foid-bearing monzodiorite (An < 50) Foid-bearing monzogabbro (An > 50)
F = 0-10, P >90	Foid-bearing diorite (An < 50) Foid-bearing gabbro (An > 50)
F = 10-60, P <10	Foid syenite
F = 10-60, P = 10-50	Foid monzosyenite
F = 10-60, P = 50-90	Foid monzodiorite (An < 50) Foid monzogabbro (An > 50)
F = 10-60, P >90	Foid diorite (An < 50) Foid gabbro (An > 50)
F > 60	Foidolites

Q = quartz/(quartz = alkali feldspar = plagioclase)
F = feldspathoids/(feldspathoids = alkali feldspar = plagioclase)
M = color index
An = % anorthite inplagioclase

Table 3
Modal Classification of Volcanic Igneous Rocks

Modal Values	Classification
Q > 60	Not igneous
Q = 20-60, P <10	Alkali feldspar rhyolite
Q = 20-60, P = 10-65	Rhyolite
Q = 20-60, P = 65-90	Dacite
Q = 20-60, P >90	Dacite
Q = 5-20, P <10	Alkali feldspar quartz trachyte
Q = 5-20, P = 10-35	Quartz trachyte
Q = 5-20, P = 35-65	Quartz latite
Q = 5-20, P = 65-90	In all six fields, the names andesite and basalt are applied; basalt is used if SiO_2 < 52wt % after H_2O and CO_2 are deleted and the analysis recalculated to sum 100%
Q = 5-20, P >90	
Q = 0-5, P = 65-90	
Q = 0-5, P >90	
F = 0-10, P = 65-90	
F = 0-10, P >90	
Q = 0-5, P <10	Alkali feldspar trachyte
Q = 0-5, P = 10-35	Trachyte
Q = 0-5, P = 35-65	Latite
F = 0-10, P <10	Foid-bearing alkali feldspar quartz trachyte
F = 0-10, P = 10-35	Foid-bearing trachyte
F = 0-10, P = 35-65	Foid-bearing latite
F = 10-60, P <10	Phonolite
F = 10-60, P = 10-50	Tephritic phonolite
F = 10-60, P = 50-90	Phonolitic tephrite
F = 10-60, P > 90	Tephrite (olivine < 10%) Basanite (olivine > 10%)
F > 60	Foidite

Q = quartz/(quartz = alkali feldspar = plagioclase)
F = feldspathoids/(feldspathoids = alkali feldspar = plagioclase)

- groundmass. *Mortar structure* applies to nonorientated arrangements, and *phacoidal*, *flaser*, and *augen structure* apply to lenticular arrangements.

7.3.2 Rock Names.

7.3.2.1 *Schistose Rocks.*

- Schist – grains can be seen without using a microscope.
- Phyllite – all (or almost all) grains of groundmass are microscopic, but cleavage have sheen caused by reflections from platy or linear minerals; commonly corrugated.
- Slate – grains are microscopic; very cleavable; surface dull; tougher than shale and cleavage commonly oblique to bedding.

- Phyllonite – appearance like phyllite but formed by cataclasis (see mylonite) and recrystallization commonly of coarser-grained rocks, as indicated by relict rock slices, slip folds, and prophyroclasts.

7.3.2.2 *Granoblastic Rocks.*

- Granulite or Granofels – granoblastic rocks, irrespective of mineral composition; because granulite can connote special compositions and conditions or origin, granofels may be preferred.
- Quartzite, marble, and amphibolite – compositional names that generally connote granoblastic texture; exceptions should be modified for clarity, as schistose quartzite or plagioclase hornblende schist.
- Tactite (skarn) – heterogeneous calc-sillicate granulites and related metasomatic rocks of typically uneven grain.

7.3.2.3 *Hornfelsic Rocks.* All called hornfels, or, if relict features are clear, hornfelsic may be used with the original rock name (as hornfelsic andesite)

7.3.2.4 *Semischistotose (Gneissic) Rocks.*

- Semischist – fine-grained (typically less than 1.4 mm) so that individual platy or lineate grains are indistinct; relict features often common.
- Gneiss – generally coarser than ½ mm with small aggregates of platy or lineate grains forming separate lenses, bladed, or streaks in otherwise granoblastic rock. Platy or lineate structures may be distributed evenly through the rock or may be concentrated locally so that some layers or lenses are granoblastic or schistose (banded gneiss).

7.3.2.5 *Cataclastic Rocks.* Where original nature of rock is still apparent, rock name can be modified by suitable adjectives (as cataclastic granite, flaser gabbro, phacoidal rhyollite).

- Mylonite – crushing so thorough that rock is largely aphanitic and commonly dark-colored; may be layered and crudely folliated but not schistose like phyllonite; porphyroclasts commonly rounded or lenticular.

- Ultrmylonite, pseudotachyylyte – aphanitic to nearly vitreous-appearing dark rock commonly injected as dikes into adjoining rocks.

7.3.2.6 Relict and Special Textures and Structures. If textures of low-grade metamorphic rocks are dominantly relict, original rock names may be modified (as massive metabasalt, semischistose met-andesite). If hydrothermal alteration has produces prominent new minerals, names such as chloritized diorite and sercitized granite can be used.

Strongly metasomatized rocks with coarse or unusual textures may require special names such as gneissen, quartz-schorl rock, and corundum-mica rock.

- Magmatite – a composite rock composed of igneous or igneous-appearing and/or metamorphic materials that are generally distinguishable megascopically.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

All completed lithologic logs shall be placed in the project file at project completion.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #32

FIELD SAMPLING WITH ENCORE™ SAMPLER

1.0 PURPOSE

1.1 The purpose of this standard operating procedure (SOP) is to provide project team employees with the proper method to collect and ship soil samples collected by an EnCore™ sampler.

2.0 SCOPE AND APPLICABILITY

2.1 Procedures defined here are followed by project team employees for proper collection and shipment of EnCore™ samplers.

3.0 REFERENCES

3.1 En Novative Technologies, Inc., SW846 Method 5035 Field Sampling Guide, February 1998.

4.0 DEFINITIONS

VOC – Volatile Organic Compounds

5.0 GENERAL

5.1 Collection and storage of soils for VOC analysis using current USEPA methodology has changed since the promulgation of SW846 Method 5035. The EnCore™ Sampler is one of three collection options promulgated from the change in SW846 Method 5035. The other two collections are Methanol Preservation (SOP 30.0) and Acid Preservation. This SOP discusses only the collection technique of the EnCore™ Sampler.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall ensure that the EnCore™ Sampler procedures used will adhere to this SOP.

6.2 The **Field Supervisor** is responsible for the supervision of daily operation as related to EnCore™ Sampler activities.

6.3 The **Field Geologist** is responsible for following the procedures outlined in this SOP.

7.0 PROCEDURES

7.1 Encore™ Sampler Collection For Low Level Analyses (≥ 1 μg/Kg)

7.1.1 <u>EnCore™ Sampling</u>. Each sample point requires:

- Two 5g samplers.
- One 25g sampler or one 5g sampler for screening and/or high level analysis. (The sampler size used will be dependent on who is doing the sampling and who is doing the laboratory analysis).
- One dry weight cup.
- One T-handle.
- Paper toweling.

<u>Procedure Sampling</u>

1. Remove sampler and cap from package and attach T-handle to sampler body.
2. Quickly push sampler into a freshly exposed surface of soil until the sampler is full.
3. Use paper toweling to quickly wipe the sampler head so that the cap can be tightly attached.
4. Push cap on with a twisting motion to attach cap.
5. Fill out label and attach to sampler.
6. Repeat procedure for the other two samplers.
7. Collect dry weight sample – fill container.
8. Store samplers at 4 degrees Celcius.
9. Ship sample containers with plenty of ice to the laboratory within 40 hours of collection.

7.1.2 Acid Preservation Sampling for Low Level Analyses (≥ or equal to 1 µg/kg). Each sample point requires:

- One 40 ml VOA vial with acid preservative (for field testing of soil pH).
- Two pre-weighted 40 ml VOA vials with acid preservative and stir bar (for lab analysis).
- Two pre-weighted 40 ml VOA vials with water and stir bar (in case samples effervesces).
- One pre-weighted jar that contains methanol or a pre-weighted empty jar accompanied with a pre-weighted vial that contains methanol (for screening sample and/or high level analysis).
- One dry weight cup.
- One 2 oz jar with NaHSO4 acid preservative (in case additional acid is needed sue to high soil pH).
- One scoop capable to deliver about one gram of solid sodium bisulfate.
- pH paper.
- Weighing balance that weighs to 0.01 gram (filed balances may not reliably weigh to 0.01 gram).
- Set of balance weights used in daily balance calibration.
- Gloves for working with pre-weighted sample vials.

Procedure Field Chemistry for Testing Effervescing Capacity of Soils

1. Place 5 grams of soil into vial that contains acid preservative and no stir bar.
2. Do not cap this vial as it may EXPLODE upon interaction with the soil.
3. Observe the sample for gas evolution (due to carbonates in the soil).
4. If vigorous or sustained gas evolution occurs, then acid preservation is not acceptable to preserve the sample. In this case, the samples

need to be collected in the VOA vials with only water and a stir bar. The vials with acid preservative CANNOT be used.

5. If a small amount or no gas evolution occurs, then acids preservation is acceptable to preserve the sample. Keep this testing vial for use in the buffering testing detailed below. In this case, the samples need to be collected in the VOA vials with the acid preservative and a stir bar.

Procedure Field Chemistry for Testing Buffering Capacity of Soils

1. If acid preservation is acceptable for sampling soils than the sample vial that was used in the effervescing testing can be used here for the buffering testing.
2. Cap the vial that contains 5 grams of soil, acid preservative and no stir bar from Step #1 in the effervescing testing.
3. Shake the vial gently to attempt to make a homogenous solution.
4. When done, open the vial and check the pH of the acid solution with the pH paper.
   - If the pH paper reads below 2 then the sampling can be done in the two pre-weighted 40 ml VOA vials with the acid preservative and stir bar. Since the pH was below 2, it is not necessary to add additional acid to the vials.
   - If the pH paper reads above 2, then additional acid needs to be added to the sample.
5. Use the jar with the solid sodium bisulfate acid and add another one gram of acid to the sample.
6. Cap the vial and shake thoroughly again.
7. When done, open the vial and check the pH of the acid solution with a new piece of pH paper.
   - If the pH paper reads below 2 then the sampling can be done in the two pre-weighted 40 ml VOA vials with the acid preservative and stir bar and one extra gram of acid.

- Make a note of the extra gram of acid needed so the same amount of extra acid can be added to the vials the lab will analyze.
- If the pH paper reads above 2, then add another gram of acid and repeat this procedure one more time.

Procedure Sampling

1. Wear gloves during all handling of pre-weighed vials.
2. Quickly collect a 5 gram sample using a cut off plastic syringe or other coring device designed to deliver 5 grams of soil from a freshly exposed surface of soil.
3. Carefully wipe exterior of sample collection device with clean paper toweling.
4. Quickly transfer to the appropriate VOA vial, extruding with caution so that the solution does not splash out of the vial.
5. Add more acid if necessary (this is based on the buffering testing discussed on the previous section).
6. Use the paper toweling and quickly remove any soil off of the vial threads.
7. Cap vial and weigh the jar to the nearest 0.01 gram.
8. Record exact weight on the sample label.
9. Repeat sampling procedure for the duplicate VOA vial.
10. Weigh the vial with methanol preservative in it to 0.01 gram. If the with of the vial with methanol varies by more than 0.01 gram from the original weight recorded on the vial - discard the vial. If the weight is within tolerance it can be used for soil preservation below.
11. Tare the empty jar or the jar that contains the methanol preservative.
12. Quickly collect a 25 gram or 5 gram sample using a cutoff plastic syringe or other coring device designed to deliver 25 gram or 5 gram

of soil from a freshly exposed surface of soil. The 25 gram or 5 gram is dependent on who is doing the sampling and who is doing the laboratory analysis.

13. Carefully wipe the exterior of the collection device with clean papa toweling.

14. Quickly transfer the soil to an empty soil jar that contains methanol. If extruding into a jar that contains methanol be careful not splash the methanol outside of the vial. Again, the type of jar received is dependent on who is doing the laboratory analysis.

15. If the jar used to collect the soil plug was empty before the soil was added, immediately preserve with the methanol provided –0 using only one vial of methanol preservative per sample jar.

16. Use the paper toweling and remove any soil off of the vial treads and cap the jar.

17. Weigh the jar with the soil in it to 0.10 gram and record the weight on the sample label.

18. Collect dry weight sample – fill container.

19. Store samples at 4 degrees Celsius.

20. Ship containers with plenty of ice and per DOT regulation to the laboratory.

7.2 Encore™ Sampler Collection For High Level Analyses ($\geq$ 200 µg/Kg)

7.2.1 EnCore™ Sampling. Each sample point requires:

- One 25g sampler or one 5g sampler. (The sampler size used will be dependent on who is doing the sampling and who is doing the laboratory analysis).
- One dry weight cup.
- One T-handle.
- Paper toweling.

Procedure Sampling

1. Remove sampler and cap from package and attach T-handle to sampler body.

2. Quickly push sampler into a freshly exposed surface of soil until the sampler is full.

3. Use paper toweling to quickly wipe the sampler head so that the cap can be tightly attached.

4. Push cap on with a twisting motion to attach cap.

5. Fill out label and attach to sampler.

6. Collect dry weight sample – fill container.

7. Store samplers at 4 degrees Celsius.

8. Ship sample containers with plenty of ice to the laboratory within 40 hours of collection.

7.2.2 Methanol Preservation Sampling. Each sample point requires:

- One pre-weighted jar that contains methanol or a pre-weighted empty jar accompanied with a pre-weighted vial that contains methanol.
- One dry weight cup.
- Weighing balance that weighs to 0.01 gram (filed balances may not reliably weigh to 0.01 gram).
- Set of balance weights used in daily balance calibration.
- Gloves for working with pre-weighted sample vials.
- Paper toweling.

Procedure Sampling

1. Wear gloves during all handling of pre-weighed vials.

2. Weigh the vial with methanol preservative in it to 0.01 gram. If the with of the vial with methanol varies by more than 0.01 gram from the

original weight recorded on the vial - discard the vial. If the weight is within tolerance it can be used for soil preservation below.

3. Tare the empty jar or the jar that contains the methanol preservative.
4. Quickly collect a 25 gram or 5 gram sample using a cutoff plastic syringe or other coring device designed to deliver 25 gram or 5 gram of soil from a freshly exposed surface of soil. The 25 gram or 5 gram is dependent on who is doing the sampling and who is doing the laboratory analysis.
5. Carefully wipe the exterior of the collection device with clean papa toweling.
6. Quickly transfer the soil to an empty soil jar that contains methanol. If extruding into a jar that contains methanol be careful not splash the methanol outside of the vial. Again, the type of jar received is dependent on who is doing the laboratory analysis.
7. If the jar used to collect the soil plug was empty before the soil was added, immediately preserve with the methanol provided –0 using only one vial of methanol preservative per sample jar.
8. Use the paper toweling and remove any soil off of the vial treads and cap the jar.
9. Weigh the jar with the soil in it to 0.10 gram and record the weight on the sample label.
10. Collect dry weight sample – fill container.
11. Store samples at 4 degrees Celsius.
12. Ship containers with plenty of ice and per DOT regulation to the laboratory.

8.0 RECORD KEEPING REQUIREMENTS AND REFERENCE TO FORMS

8.1 A field logbook will be assigned to each sampling team for each project. In addition, a copy of the pages should be placed in the project file in case the logbook is lost or destroyed. Upon completion of the project, the field log will remain in the project files.

9.0 ATTACHMENTS

Not applicable

BENICIA SOP #33

GROUNDWATER SAMPLING USING PASSIVE DIFFUSION BAG SAMPLERS

1.0 PURPOSE

1.1 This standard operating procedure (SOP) provides the detailed procedures for collecting groundwater samples for Volatile Organic Compounds (VOCs) in the field using a Passive Diffusion Bag (PDB).

2.0 SCOPE

2.1 This procedure applies to all Project team personnel and subcontractors who collect groundwater samples.

2.2 This sampling procedure is only applicable to non-polar VOCs.

2.3 This SOP presents the methods for PDB sampler deployment and recovery.

3.0 REFERENCES

3.1 U.S. Geological Survey (USGS). 2001. User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells [Water-Resources Investigations Report 01–4060], (Prepared in cooperation with the U.S. Air Force; U.S. Naval Facilities Engineering Command; U.S. Environmental Protection Agency (EPA); Federal Remediation Technologies Roundtable; Defense Logistics Agency; U.S. Army Corps of Engineers (USACE); and Interstate Technology Regulatory Cooperation Workgroup).

3.1 U.S. EPA. 1990. Procedures to Schedule and Complete Sampling Activities in Cooperation with EPA Region VII Environmental Services Division. February.

3.2 U.S. EPA Region VII. 1991. Environmental Services Division Operations and Quality Assurance Manual. February.

3.3 Personal Communications. 2001. Columbia Analytical Passive Diffusion Bag Presentation by Ed Wilson.

4.0 DEFINITIONS

4.1 Groundwater. Water in a saturated zone or stratum beneath the surface of land or beneath the bottom of surface water.

4.2 Custody. The physical control of an object, in this case of an environmental sample.

4.3 Chain of custody. Refers to the individuals who, sequentially over a period of time, have physical custody of the sample.

4.4 Chain of custody record. The documentation of the chain-of-custody showing times, dates, and names of the individuals relinquishing and receiving the samples identified on the record.

5.0 GENERAL

5.1 Water-filled PDB samplers described in this SOP are suitable for obtaining concentrations of a variety of VOCs in groundwater at monitoring wells. The suggested application of the method is for long-term monitoring of VOCs in groundwater wells at well-characterized sites.

The effectiveness of the use of a single PDB sampler in a well is dependent on the assumption that there is horizontal flow through the well screen and that the quality of the water is representative of the groundwater in the aquifer directly adjacent to the screen. If there are vertical components of intra-borehole flow, multiple intervals of the formation contributing to flow, or varying concentrations of VOCs vertically within the screened or open interval, then a multiple deployment of PDB samplers within a well may be more appropriate for sampling the well. A typical PDB sampler consists of a low-density polyethylene (LDPE) lay-flat tube closed at both ends and containing deionized water. The sampler is positioned at the target horizon of the well by attachment to a weighted line or fixed pipe.

The amount of time that the sampler should be left in the well prior to recovery depends on the time required by the PDB sampler to equilibrate with ambient water and the time required for the environmental disturbance caused by sampler deployment to return to ambient conditions.

5.2 The use of PDB samplers for collecting groundwater samples from wells offers a cost-effective approach to long-term monitoring of VOCs at well-characterized sites.

5.3 The samplers consist of deionized water enclosed in a LDPE sleeve and are deployed adjacent to a target horizon within a screened or open interval of a well. The suggested application is for long-term monitoring of VOCs in groundwater wells. Where the screened interval is greater than 10 feet, the potential for contaminant stratification and/or intra-borehole flow within the screened interval is greater than in screened intervals shorter than 10 feet. It is important that the vertical distribution of contaminants be determined in wells having 10-feet-long well screens, and that both the vertical distribution of contaminants and the potential for intra-borehole flow be determined in wells having screens longer than 10 feet. For many VOCs, the VOC concentration in water within the sampler approaches the VOC concentration in water outside of the PDB sampler over an equilibration period. The resulting concentrations represent an integration of chemical changes over the most recent part of the equilibration period. The approach is inexpensive and has the potential to eliminate or substantially reduce the amount of purge water removed from the well.

5.4 A variety of PDB samplers have been utilized in well applications. Although the samplers vary in specific construction details, a typical PDB sampler consists of a 1- to 2-feet-long LDPE tube closed at both ends and containing laboratory-grade deionized water. The typical diameter for PDB samplers used in a 2-inch-diameter well is approximately 1.2 inches; however, other dimensions may be used to match the well diameter. Equilibration times may be longer for larger diameter PDB samplers. On the outside of the PDB sampler, a low-density polyethylene-mesh sometimes is used for protection against abrasion in open boreholes and as a means of attachment at the prescribed depth. The PDB sampler can be positioned at the target horizon by attachment to a weighted line or by attachment to a fixed pipe.

PDB samplers for use in wells are available commercially. Authorized distributors as of March 2001 are Columbia Analytical Services (800-695-7222; www@caslab.com) and Eon Products (800-474-2490; www.eonpro.com). A current list of vendors and PDB-sampler construction details can be obtained from the U.S. Geological Survey Technology Transfer Enterprise Office, Mail Stop 211, National Center, 12201 Sunrise Valley Drive, Reston, Virginia 20192 (telephone 703-648-4344; fax 703-648-4408). PDB samplers employ patented technology (U.S. patent number 5,804,743), and therefore, require that the user purchase commercially produced samplers from a licensed manufacturer or purchase a nonexclusive license for sampler construction from the U.S. Geological Survey Technology Enterprise Office at the above address.

5.5 Summary of PDB Sampler Advantages and Limitations

5.5.1 The following are the advantages of PDB Sampler:

- PDB samplers have the potential to eliminate or substantially reduce the amount of purge water associated with sampling.
- PDB samplers are inexpensive.
- The samplers are easy to deploy and recover.
- Because PDB samplers are disposable, there is no downhole equipment to be decontaminated between wells.
- A minimal amount of field equipment is required.
- Sampler recovery is rapid. Because of the small amount of time and equipment required for the sampling event, the method is practical for use where access is a problem or where discretion is desirable (that is, residential communities, business districts, or busy streets where vehicle traffic control is a concern).
- Multiple PDB samplers, distributed vertically along the screened or open interval, may be used in conjunction with borehole flow meter testing to gain insight on the movement of contaminants into and out of the well screen or open interval or to locate the zone of highest concentration in the well. Analytical costs when using multiple PDB samplers sometimes can be reduced by selecting a limited number of

the samplers for laboratory analysis based on screening by using field gas chromatography at the time of sample collection.

- Because the pore size of LDPE is only about 10 angstroms or less, sediment does not pass through the membrane into the bag. Thus, PDB samplers are not subject to interferences from turbidity. In addition, none of the data collected suggest that VOCs leach from the LDPE material or that there is a detrimental effect from the PDB material on the VOC sample.

5.3.2 The following are the limitations of the PDB Sampler:

- PDB samplers integrate concentrations over time. This may be a limitation if the goal of sampling is to collect a representative sample at a point in time in an aquifer where VOC-concentrations substantially change more rapidly than the samplers equilibrate.
- Water-filled polyethylene PDB samplers are not appropriate for all compounds. For example, although methyl-*tert*-butyl ether and acetone and most semivolatile compounds are transmitted through the polyethylene bag, laboratory tests have shown that the resulting concentrations were lower than in ambient water. Thus, these samplers should not be used to sample for polar or semi-volatile compounds.
- PDB samplers rely on the free movement of water through the well screen. In situations where groundwater flows horizontally through the well screen, the VOC concentrations in the open interval of the well probably are representative of the aquifer water in the adjacent formation. In these situations, the VOC concentration of the water in contact with the PDB samplers, therefore, the water within the diffusion samplers probably represents local conditions in the adjacent aquifer. However, if the well screen is less permeable than the aquifer or the sandpack, then under ambient conditions, flowlines may be diverted around the screen. Such a situation may arise from

inadequate well development or from iron bacterial fouling of the well screen. In this case, the VOC concentrations in the PDB samplers may not represent concentrations in the formation water because of inadequate exchange across the well screen. PDB samplers have not yet been adequately tested to determine their response under such conditions.

- VOC concentrations in PDB samplers represent groundwater concentrations in the vicinity of the screened or open well interval that move to the sampler under ambient flow conditions. This is a limitation if the groundwater contamination lies above or below the well screen or open interval, and requires the operation of a pump to conduct contaminants into the well for sampling.
- In cases where the well screen or open interval transects zones of differing hydraulic head and variable contaminant concentrations, VOC concentrations obtained using a PDB sampler may not reflect the concentrations in the aquifer directly adjacent to the sampler because of vertical transport in the well. However, a vertical array of PDB samplers, used in conjunction with borehole flow meter testing, can provide insight on the movement of contaminants into or out of the well. This information then can be used to help determine if the use of PDB samplers is appropriate for the well, and to select the optimal vertical location(s) for the sampler deployment.
- In wells with screens or open intervals with stratified chemical concentrations, the use of a single PDB sampler set at an arbitrary (by convention) depth may not provide accurate concentration values for the most contaminated zone. However, multiple PDB samplers distributed vertically along the screened or open interval, in conjunction with pump sampling (as appropriate), can be used to locate zone(s) of highest concentration in the well. Multiple PDB samplers also may be needed to track the zone of maximum concentration in wells where flow patterns through the screened

interval change as a result of ground-water pumping or seasonal water-table fluctuations.

6.0 RESPONSIBILITIES

6.1 The **Project Manager** shall assure that the sampling procedures used to obtain samples will represent the environment being investigated.

6.2 The **Field Supervisor** shall ensure that specified sampling procedures are followed; samples are labeled, handled, and controlled correctly; and strict chain-of-custody is initiated, maintained, and documented.

6.3 Personnel responsible for collecting groundwater samples will do so in accordance with this SOP.

7.0 PROCEDURES

All information and procedures will be documented in the field log book or on the water sampling log.

7.1 The procedures specified in SOP 11.0, Sampling Equipment Decontamination shall be followed for decontamination of sampling equipment and for personnel decontamination. Decontaminate all water level measurement probes, bailers, and other sampling devices prior to each sampling event. If new, dedicated equipment is used, thoroughly decontaminate and rinse it with distilled water before placement in the well. Mobile decontamination supplies shall be provided so that equipment can be decontaminated in the field. Check all measuring devices for proper operation. Calibrate any instruments as necessary. Decontaminated solutions shall be placed in the container with purged well water for disposal.

7.2 Field measurements for pH, temperature, and specific conductance shall be made in accordance with SOPs found in the Benicia Arsenal Quality Assurance Project Plan and the manufacturer's instructions. Electronic equipment used during sampling and equipment-specific procedures, include:

7.2.1 temperature (SOP 23.0, Field Measurement of Temperature)

7.2.2 pH meter (SOP 22.0, Field Measurement of pH)

Calibration: Prior to use every day

Recalibrated if turned off

Procedure: Done in the shade

Record ambient temperature.

7.2.3 conductivity meter (SOP 24.0, Field Measurement of Specific Conductance)

Calibration: Prior to use every day (recalibrated if turned off)

7.2.4 water level measurement probe (SOP 25.0, Field Measurement of Water Levels)

7.2.5 Due to the required sensitivity of pH measurements, measurement and calibration data related to these parameters shall be recorded. Calibration times and all new data shall be recorded in the logbook.

7.3 A variety of approaches can be used to deploy the PDB samplers in wells. A typical deployment approach, described in this section, is to attach the PDB samplers to a weighted line. It also is acceptable to attach the weights directly to the PDB sampler if the attachment point is of sufficient strength to support the weight. The weights attached to the bottom of the line are stainless steel and can be reused, but shall be thoroughly decontaminated with a detergent before the first use or before using in a different well. Rope, such as 90 pound, 3/16 inch braided polyester, will be used as the line for single-use applications if it is of sufficient strength to support the weight and sampler, is nonbuoyant, and is subject to minimal stretch; however, the rope shall not be reused because of the high potential for cross contamination. Stainless-steel or Teflon-coated stainless-steel wire is preferable. The weighted lines shall not be reused in different wells to prevent carryover of contaminants. A possible exception is coated stainless-steel wire, which can be reused after sufficient decontamination.

7.4 The PDB samplers should not contact non-aqueous phase liquid (NAPL) during deployment or retrieval to prevent cross contamination.

7.5 PDB samplers are available either pre-filled (field ready) with laboratory-grade deionized water, or unfilled. The unfilled samplers are equipped with a plug and funnel to allow for field filling and sample recovery. To fill these samplers, remove the plug from the sampler bottom, insert the short funnel into the sampler, and pour laboratory-grade deionized water into the sampler. The sampler should be filled until water rises and stands at least half way into the funnel. Remove excess bubbles from the sampler. Remove the funnel and reattach the plug. A small air bubble from the plug is of no concern.

7.6 The following steps should be used before deploying the PDB Samplers in wells:

7.6.1 Note the condition of the outer well casing, concrete well pad, protective posts (if present), and any unusual conditions of the area around the well in the field logbook. The well may also be photographed;

7.6.2 Take appropriate readings in the breathing zone with air monitoring equipment (PID) according to the health and safety plan. If air monitoring readings are elevated (above background) at the wellhead initially, breathing zone readings should be taken throughout purging and sampling activities;

7.6.3 Note the condition of the inner well cap and casing;

7.6.4 Identify the measuring point (e.g., notch on north side, top of PVC well casing);

7.6.5 Measure and record the depth of the static water level with a water level indicator (to nearest 0.01 foot) from the measuring point on the well casing and record the time. The measurement should be made at a minimum of two times, until two consecutive readings are within 0.01 foot of each other;

7.6.6 Measure and record the total depth of well from the same measuring point on the casing with a water level indicator;

7.7 The following steps should be used for deploying PDB samplers in wells:

7.7.1 Attach a stainless-steel weight to the end of the line. Sufficient weight should be added to counterbalance the buoyancy of the PDB samplers.

This is particularly important when multiple PDB samplers are deployed. One approach, discussed in the following paragraphs, is to have the weight resting on the bottom of the well, with the line taut above the weight. Alternatively, the PDB sampler and weight may be suspended above the bottom, but caution should be exercised to ensure that the sampler does not shift location. Such shifting can result from stretching or slipping of the line or, if multiple samplers are attached end-to-end rather than to a weighted line, stretching of the samplers.

7.7.2 Calculate the distance from the bottom of the well, or top of the sediment in the well, up to the point where the PDB sampler is to be placed. A variety of approaches can be used to attach the PDB sampler to the weight or weighted line at the target horizon. The field-fillable type of PDB sampler is equipped with a hanger assembly and weight that can be slid over the sampler body until it rests securely near the bottom of the sampler. When this approach is used with multiple PDB samplers down the same borehole, the weight shall only be attached to the lowermost sampler. An additional option is to use coated stainless-steel wire as a weighted line, making loops at appropriate points to attach the upper and lower ends of PDB samplers. Where the PDB sampler position varies between sampling events, movable clamps with rings can be used. When using rope as a weighted line, a simple approach is to tie knots or attach clasps at the appropriate depths. Nylon cable ties or stainless-steel clips inserted through the knots can be used to attach the PDB samplers. An approach using rope as a weighted line with knots tied at the appropriate sampler-attachment points is discussed below.

7.7.2.1 For 5-feet-long or shorter well screens, the center point of the PDB sampler shall be the vertical midpoint of the saturated well-screen length. If, however, independent evidence is available showing that the highest concentration of contaminants enters the well from a specific zone within the screened interval, then the PDB sampler shall be positioned at that interval. In long-term monitoring situations, the position of the PDB Sampler is paramount.

Regardless of where the PDB Sampler is placed, it must be placed in the same position within the well each time a new PDB Sampler is deployed.

7.7.2.2 For 5- to 10-feet-long well screens, it is advisable to utilize multiple PDB samplers vertically along the length of the well screen for at least the initial sampling. The purposes of the multiple PDB samplers are to determine whether contaminant stratification is present and to locate the zone of highest concentration. The midpoint of each sampler shall be positioned at the midpoint of the interval to be sampled. In long-term monitoring situations, the position of the PDB Sampler is paramount. Regardless of where the PDB Sampler is placed, it must be placed in the same position within the well each time a new PDB Sampler is deployed. For 1.5-feet-long samplers, at each sampling depth in the screened interval, make two attachment points will be made on the weighted line at a distance of about 1.5 feet apart. The attachment points shall be positioned along the weighted line at a distance from the bottom end of the weight such that the midpoint between the knots will be at the desired sampling depth along the well screen. Sampler intervals are variable, but a simple approach is to use the top knot/loop of one sampler interval as the bottom knot/loop for the overlying sampler interval.

7.7.2.3 PDB samplers shall not be used in wells having screened or open intervals longer than 10 feet unless used in conjunction with borehole flow meters or other techniques to characterize vertical variability in hydraulic conductivity and contaminant distribution or used strictly for qualitative reconnaissance purposes. This is because of the increased potential for cross contamination of water-bearing zones and hydraulically driven mixing effects that may cause the contaminant stratification in the well to differ from the contaminant stratification in the adjacent aquifer material. If it is necessary to sample such wells, then multiple PDB samplers shall be installed vertically across the screened or open interval to determine the zone of highest concentration and whether contaminant stratification is present.

7.7.3 The samplers shall be attached to the weights or weighted line at the time of deployment. For samplers utilizing the hanger and weight assembly, the line can be attached directly to the top of the sampler. PDB samplers utilizing an outer protective mesh can be attached to a weighted line by using the following procedure:

7.7.3.1 Insert cable ties through the attachment points in the weighted line.

7.7.3.2 At each end of the PDB sampler, weave the ends of the cable ties or clamp through the LPDE mesh surrounding the sampler and tighten the cable ties. Thus, each end of the PDB sampler will be attached to a knot/loop in the weighted line by means of a cable tie or clamp. The cable ties or clamps shall be positioned through the polyethylene mesh in a way that prevents the PDB sampler from sliding out of the mesh.

7.7.3.3 Trim the excess from the cable tie before placing the sampler down the well. Caution shall be exercised to prevent sharp edges on the trimmed cable ties that may puncture the LDPE.

7.7.4 When using PDB samplers without the protective outer mesh, the holes punched at the ends of the bag, outside the sealed portion, can be used to attach the samplers to the weighted line.

7.7.5 Lower the weight and weighted line down the well until the weight rests on the bottom of the well and the line above the weight is taut. The PDB samplers should now be positioned at the expected depth. A check on the depth shall be done by placing a knot or mark on the line at the correct distance from the top knot/loop of the PDB sampler to the top of the well casing and checking to make sure that the mark aligns with the lip of the casing after deployment.

7.7.6 Secure the assembly in this position. A suggested method is to attach the weighted line shall be attached to a hook on the inside of the well cap. Reattach the well cap. The well shall be sealed in such a way as to prevent surface water invasion. This is particularly important in flush-mounted well vaults that are prone to flooding.

7.7.7 Allow the system to remain undisturbed as the PDB samplers equilibrate.

7.8 Under field conditions, the samplers should be left in place long enough for the well water, contaminant distribution, and flow dynamics to restabilize following sampler deployment. The results of borehole dilution studies show that wells can recover to 90 percent of the predisturbance conditions within minutes to several hours for permeable to highly permeable geologic formations, but may require 100 to 1,000 hours (4 to 40 days) in muds, very fine-grained loamy sands, and fractured rock, and may take even longer in fractured shales, recent loams, clays, and slightly fractured solid igneous rocks (USGS, 2001). In general, where the rate of groundwater movement past a diffusion sampler is high, equilibration times through various membranes commonly range from a few hours to a few days. Recent studies indicate that wells with good groundwater movement require 14 days for the PDB Sampler to equilibrate (Personal Communication, 2001).

7.8.1 If a heavy organic coating is observed on a PDB sampler, it is advisable to determine the integrity of the sample by comparing contaminant concentrations from the PDB sampler to concentrations from a conventional sampling method before continuing to use PDB samplers for long-term deployment in that well. Recovery of PDB samplers is accomplished by using the following approach:

7.8.1.1 Remove the PDB samplers from the well by using the attached line. The PDB samplers shall not be exposed to heat or agitated.

7.8.1.2 Examine the surface of the PDB sampler for evidence of algae, iron or other coatings, and for tears in the membrane. Note the observations in a sampling field book. If there are tears in the membrane, the sample shall be rejected. If there is evidence that the PDB sampler exhibits a coating, then this shall be noted in the validated concentration data.

7.8.1.3 Detach and remove the PDB sampler from the weighted line. Remove the excess liquid from the exterior of the bag to minimize the potential for cross contamination.

7.8.1.4 A variety of approaches may be used to transfer the water from the PDB samplers to 40-mL volatile organic analysis (VOA) vials. Whichever approach is used, the transfer of water from the PDB Sampler to VOA vials shall be completed as soon as the PDB Sampler is removed from the well. One type of commercially available PDB sampler provides a discharge device that can be inserted into the sampler. If discharge devices are used, the diameter of the opening should be kept to less than about 0.15 inches to reduce volatilization loss. Two options are presently available to recover water from the sample using discharge devices.

- One option involves removing the hanger and weight assembly from the sampler, inverting the sampler so that the fill plug is pointed upward, and removing the plug. The water can be recovered by directly pouring in a manner that minimizes agitation or by pouring through a VOC-discharge accessory inserted in place of the plug.
- The second approach involves piercing the sampler near the bottom with a small-diameter discharge tube and allowing water to flow through the tube into the VOA vials.

In each case, flow rates can be controlled by tilting or manipulating the sampler. Alternatively, the PDB sampler can be cut open at one end using scissors or other cutting devices which have been decontaminated between use for different wells. Water can then be transferred to 40-ml VOA vials by gently pouring in a manner that minimizes water agitation. Acceptable duplication has been obtained using each method. Preserve the samples according to the analytical method. The sampling vials should be stored at approximately 4 °C in accordance with standard sampling protocol. Laboratory testing suggests that there is no substantial change in the VOC concentrations in PDB samplers over the first several minutes after recovery; however, the water should be transferred from the water-filled samplers to the sample bottles immediately upon recovery.

7.8.1.5 Any unused water from the PDB sampler and water used to decontaminate cutting devices shall be disposed in accordance with local, state, and Federal regulations.

7.9 VOC sample vials shall be completely filled so the water forms a convex meniscus at the top, then capped so that no air space exists in the vial. Turn the vial over and firmly tap it to check for the presence of bubbles in the vial. If air bubbles are observed in the sample vial, remove lid and add additional water. Replace lid and check for bubbles again. Repeat until no bubbles remain in the sample vial.

- Record time of sampling;
- Replace and lock the well cap; and
- Complete field documentation including the chain of custody (COC).

7.10 QA duplicate samples are used to assess laboratory accuracy in constituent identification and quantification. QA duplicate samples consist of representative sample volumes from one groundwater sampling location. To maximize the information available in assessing total precision, duplicate samples should be collected from locations of varying contaminant concentrations. Field measurements, visual observations, and past sampling results and information on site operations will be used to select appropriate locations for duplicate analyses. QA duplicate samples should be collected by taking aliquots from a single PDB sampler. Equal volumes are submitted to two or more laboratories for analysis using identical methods for preservation, packaging, and submission. The party receiving the QA duplicate sample completes a "Receipt for Samples

Form" and provides a copy to the project team. The results are compared as a check on laboratory accuracy. Because two samples are analyzed, environmental variability and precision (from one location to another) is assessed.

7.11 Field duplicate samples are collected to assess the total precision of field and laboratory components of the field investigation. Field duplicate samples are similar to QA duplicate samples except that the samples are stored in the same cooler and shipped to the same laboratory. Whenever possible, the sample identification numbers for the characteristic sample and its duplicate shall be independent such that the receiving laboratory is not able to distinguish which samples are duplicates prior to analysis. This minimizes the potential for laboratory bias.

7.12 An extra volume of sample media may be collected during the sampling event for performance of matrix spike (MS)/matrix spike duplicate (MSD) analyses by the laboratory to assess laboratory accuracy, precision, and matrix interference. The samples are collected in the same manner as duplicate samples and are labeled extra volume samples for MS/MSD. The sample volumes required for these analyses are coordinated with the laboratory and described in the FSIP. Following shipment of the samples to the laboratory, the laboratory prepares MS and MSD samples and calculates the percent recovery and relative percent difference in concentrations between the samples.

7.14 Performance Evaluation (PE), or pre-spiked audit samples, may be used to assess laboratory extraction efficiency and accuracy in constituent identification and quantification. These samples are helpful in assessing potential bias of analytical methods. They are also commonly used to evaluate the accuracy of the laboratory procedures. These samples are generally prepared by an independent laboratory and shipped in pre-sealed containers to the field to be included with the samples sent to the laboratory performing the analysis of site samples. The analytes of interest and corresponding analyte concentrations for the spike samples are specified in the request to the independent laboratory providing the samples in accordance with the FSIP. These samples are assigned an I.D. number, stored in an iced cooler, and shipped blind to the laboratory with the other samples.

7.15 Background groundwater samples are used to assess the range of concentrations in the vicinity of the site which are not the result of site activities. These samples are taken from areas not anticipated to have been impacted by historical site operations (i.e., away from the containment source areas and hydraulically upgradient).

The background samples are collected at the locations and depths specified in the FSIP. Where possible, the background wells are constructed and developed in the same manner as the site monitoring wells.

7.16 Samples are identified, handled, and recorded as described in this SOP and in accordance with standard sample handling protocols indicated in the FSIP.

7.17 Field notes are kept in a bound field logbook. The following information is recorded using waterproof ink:

- Names of personnel, including name of sampler;
- Weather conditions;
- Project number and project title;
- Chain of custody numbers;
- Location and well number, condition of the well, and initial and final static water level, total well depth, and measuring point;
- Date and time of sampling;
- Decontamination information;
- Field forms for well evacuation and water quality sampling (see attached);
- Analyses to be performed by the laboratory;
- Equipment calibration information;
- Sample volume, number, and container types, method of sample collection, and sample preservation;

- QA/QC samples collected; and
- Irregularities or problems.

8.0 RECORD KEEPING REQUIREMENTS

8.1 Copies of all documentation pertinent to groundwater sampling will be placed in the project file at the conclusion of the project.

9.0 ATTACHMENTS

Not applicable