RATON BASIN BASELINE GROUNDWATER INVESTIGATION SAMPLING & ANALYSIS PLAN

Submitted to:
PETROGLYPH OPERATING COMPANY, INC.

November 30, 2006

Norwest Applied Hydrology
950 S. Cherry St., Suite 810
Denver, Colorado 80246
Tel: (303) 782-0164
Fax: (303) 782-2560
Email appliedhydrology@norwestcorp.com

www.norwestcorp.com

List of Tables

1 INTRODUCTION

It is proposed that Norwest Applied Hydrology assess baseline groundwater conditions within the Raton Basin in the vicinity of Petroglyph Operating Company, Inc. operations, hereby referred to as Petroglyph. Determination of baseline groundwater will serve as a basis of groundwater changes and or potential changes due to activities performed by Petroglyph. Potential changes within the Raton Basin groundwater hydrology include water level declines and or water quality impacts in nearby water supply wells.

Petroglyph is pumping groundwater from coals to stimulate gas flow. Groundwater withdrawals for dewatering coals in order to release natural gas has the potential to lower water levels in overlying aquifers through aquitard leakage and or direct hydraulic connections (i.e. fractures or high vertical hydraulic conductivity). Water supply wells within the same aquifer formation where dewatering occurs or within a hydraulically connected aquifer to the dewatered zones have the potential to experience lowering of water levels that could result in drying up of such wells. Additionally, potential drawdown could increase the cost of installing new wells due to increased depth to water. Typically groundwater water quality deteriorates with depth and deeper water supply wells may require water quality treatment due to potential increased salinity. Discharge of produced water may also infiltrate and recharge the shallow aquifer system potentially impacting water quality in domestic water wells requiring water treatment prior to use. Potential impacts on water supply wells would be based on the hydraulics and extractions of the production zone, connectivity of water supply zone aquifers with target zones, and monitoring locations and well water elevations.

Collection of water levels and water quality data from domestic water supply wells will allow for the establishment of existing or baseline conditions. It is unlikely that long-term historic records of water levels and or water quality in supply wells can be constructed. A survey of permitted supply well records, anecdotal observations, and of non-permitted wells, would help characterize the shallow aquifer characteristics, demands and water level trends.

2 DATA ACQUISITION

Petroglyph will review all available information (well log etc.) about the wells chosen for the monitoring program and assess the ability to perform the various monitoring and testing requested. Petroglyph would be asked to provide:

1) Contact with domestic land owners for sampling and water level measurements;
2) Existing monitoring well water level data (location, completion stratigraphy, heads);
3) Water production data (location, completion, flows);
4) Existing water quality analyses (location, completion, sample date)

Petroglyph may also provide interviews of long-term residents with wells. However, during site inspections NAH will document domestic water well information provided by the landowner as well as through observations.

2.1 SITE INSPECTION

The site inspection will include photo documentation of the well, ancillary support facilities such as a stock tank, well house, windmills, and above ground piping. Locations will be identified using a handheld global positioning system (GPS) unit. The site inspection will be coordinated with baseline data collection activities if appropriate. Ability to collect water levels and water quality samples will be assessed and collected if possible. If water levels and water quality samples cannot be easily obtained during the initial inspection the decision will be made whether to return with additional equipment necessary to obtain the data or to exclude from the list of collection sites. It would be important to interview the owner or user of the well to obtain information about construction, history of usage, and current usage. Also some of the items listed below may not be visible (e.g. screen type) but the owner may have anecdotal information not available from the state engineers office. The major items to include during this inspection include:

a) General well construction and condition

Age or date of construction (from log or owner)
Location with respect to surface influences (septic tanks, drainages, ponds, etc.)
General condition of the well (corrosion, wellhead seal, annular seal)
Casing and wellhead construction material (PVC, black iron, etc.)
Screen type (from log or owner)
Completion zone (from log or owner)
Pumping equipment (type, depth setting, previous problems, etc.)
Sanitary seal (condition, access for water level measurement)
Ability to measure a static water level
Ability to measure pumping rate
Ability to take water sample (prior to water entering a tank or any treatment system)
Ability to measure any methane gas build-up at the wellhead

b) Well use

Historical use

Current use
Pumping rate when operational
Typical pumping cycle
Typical average monthly withdrawal and seasonal variation

The above information will be detailed in a form by the NAH field person. A sample form is provided in Appendix A.

2.2 GROUNDWATER POTENTIOMETRIC DATA

The construction of a pre-development, including CBM and domestic water wells, groundwater potentiometric surface may at this time be difficult to establish due to the absence of historic data and the current effects due to CBM and domestic groundwater extractions. However, this is a critical aspect of determining impacts to domestic and private water wells due to CBM development. A review of literature and governmental data will be required to include all possible pre-development data. Additionally, groundwater level data from private landowner wells is required to establish a current potentiometric surface. In order to account for seasonal groundwater fluctuations it is recommended that water level data be collected during spring and fall/winter to identify maximum and minimum water levels due to spring infiltration and recharge, and increased domestic summer extractions for irrigation and livestock watering, respectively. The current domestic water levels will serve as a baseline for potential future impacts due to continued CBM and domestic groundwater extractions.

If the well is being actively used, it is important to know the history of pumping at the time the water level measurement is taken. Most domestic and stock wells run intermittently based on the level or pressure in a holding tank. It is best to shut the pump off for at least 24 hrs prior to measurement. If this is not practical, then the approximate pumping rate, the typical pumping cycle, and the time of the water level measurement with respect to the cycle should be documented.

There must be access at the wellhead to allow a static water level measurement to be made using a standard electric probe, a pressure transducer, or a bubbler-line. For most small domestic wells that contain submersible pumps, this is usually not the case because the sanitary seal may not have a port. In addition, the water level measuring cable can easily get entangled with the pump electric cable. For transducer or electric probe measurements, it is preferable to take water level measurements inside a sounding tube if possible. This avoids problems with entanglement of the water level measuring device with the pump cable. The water level sounding tube, consisting of ¾-inch polyethylene pipe, should be snaked into the well to a depth below the expected minimum water level.

2.2.1 Decontamination Procedures

All fluid level monitoring and groundwater sampling equipment that comes in contact with the subsurface or groundwater at the site will be cleaned and disinfected prior to use and between sampling locations per Rule 15.6 Test Equipment Disinfection as designated by the State of Colorado Office of the State Engineer.

The cleaning and disinfection procedures include:

- Wash equipment with a solution of non-phosphate detergent and potable water
- Rinsing with sufficient potable water to remove all detergent
- Contact with chlorine solution with a concentration of at least 300 mg/L total chlorine for 15 minutes or more
- Rinsing with distilled/deionized water
- Allowing equipment to air dry for 10 minutes
- Storing and transporting equipment so that it dos not become contaminated

2.3 GROUNDWATER WATER QUALITY

2.3.1 Overview

Groundwater samples and water quality field parameters will be collected from domestic water wells. The baseline sample should be analyzed for all sensitive or critical parameters that either define water use criteria or might be influenced by CBM water mixing (e.g. for shallow wells near impoundments). If there is reason to expect some seasonal variation in water quality, it may be prudent to take samples at different times of the year to establish natural variation (see water level comment).

The following water quality data will be collected:

- Field parameters (manually during well purging and prior to sampling at each event);
- Major ion and metal concentrations, dissolved gases, TDS, TSS, and pH (each sampling event);
- Stable isotope analyses (initial sampling event and later if needed to assess water quality problems).

Table 2.1 lists the analytes sampled for and is comprised of water quality field parameters, dissolved gasses, major ion chemistry and isotopes of water that can be used to characterize groundwater and gas sources. Major ion chemistry will be analyzed at Severn Trent Laboratories (STL) while isotopes will be sent to Isotech Laboraties for analysis. While CBM groundwater extractions are less likely to impact groundwater water quality of domestic water wells directly, water quality may be impacted from surface discharge to channels or pits that recharge the shallow aquifer system. Samples from CBM produced water and domestic water wells will be used to determine whether or not the two water sources can be distinguished from one another based on water quality characteristics such that subsequent water quality changes can be assessed. It is hypothesized that water quality characteristics for the two produced waters will be different based on existing data.

Potential impacts on domestic water wells can also be supported or negated if the water characteristics are unique and CBM produced water does not vary temporally. Potential drawdown due to CBM production may be linked with production well water quality changes resulting in values resembling that of shallow domestic well water.

In addition to field parameter measurements, inorganic water quality analyses and dissolved gas analyses, field gas monitoring with a handheld unit will be implemented to measure methane and hydrogen sulphide in the field. If methane is detected a groundwater sample will be collected and analyzed for dissolved concentrations of methane (CH_4), ethane (C_2H_6), and ethene (C_2H_4). This suite of gases will be used to determine the origin of the gas whether from biogenic or thermogenic processes and can potentially be used to refute gas from CBM production zones. Stable isotopes of carbon and hydrogen can also be analyzed for further identification of gas source if needed. However, stable isotope analyses are not recommended at this time. These gases are related to CBM and isotope signatures and can be used to identify the source and origin of the gas and whether or not the presence of gas is related to CBM operations. This should be a standardized field measurement taken with a probe inside the well casing when the well is operating. If there is reason to expect some seasonal variation in water levels, it may be prudent to take methane readings at different times of the year to establish natural variation (see water level comment).

Chemistry of the production and supply well waters provided by Petroglyph is probably sufficient to distinguish shallow and production zone aquifers, though not to refute a hydraulic connection.

2.3.2 Domestic Well Sampling Procedure

Domestic wells will be sampled at the outside spigot closest to the well whenever possible. The sampler will let at least 20 gallons of water flow from the spigot before sampling. Field parameters will be monitored at domestic well locations, and these will be stable before procuring samples. The samples will be taken directly from a spigot; all hoses will be removed before sampling begins. Dissolved metals samples from domestic wells will be collected in non-preserved HDPE bottles ans sent to the laboratory for filtering and acidification .

2.3.3 Quality Assurance/Quality Control Sampling

Samples will be taken at regular intervals for quality control and assurance purposes. These samples include duplicate, replicate, and blank samples.

Duplicate samples are used to compare the results from two separate samples taken from the same location and will be taken at every tenth location with a minimum of one per day. A duplicate sample is a second set of bottles filled exactly the same way as the original sample. These bottles will be given different sample identification and a different sample time. The duplicate bottles will be filled after the original sample bottles. Wells selected for duplicate analysis will change with each sampling event and will be identified on the sampling log.

Replicate samples are used for laboratory control and for verification of data quality objectives. These samples are taken from 10% of the well locations. A replicate sample entails filling twice the number of bottles as a regular sample; all bottles are given the same sample identification and the filter is not changed between bottles. Replicate samples should be noted on the chain of custody. Wells selected for replicate analysis will change with each sampling event and will be identified on the sampling log. Replicate samples will be collected only at the request of the analytical laboratory.

Two types of blank samples may be taken during each sampling event: field blanks and equipment rinsate blanks. Blank samples are used to determine if any procedures have introduced chemicals to the samples that would not be indicative of the water being sampled. Each blank sample is a full bottle set with unique sample identification. The sample bottles are filled with laboratory-supplied deionized (DI) water. A field blank will be taken every 20 samples; field blanks are filled at one of the well locations. Trip blanks are field blanks that have been filled in the laboratory and are taken to the field and returned to the lab without opening. At least one set of trip blanks will accompany each set of samples sent to the laboratory.

Equipment rinsate blanks will be taken daily from all equipment used after the equipment has been decontaminated; the DI water is pumped through the pump and the hose reel and the discharge is sampled. Dedicated sampling pumps are not used in more than one well; therefore, a rinsate blank will not be taken. Rinsate blanks will be taken from the non-dedicated sampling pumps, if used, at the end of the sampling event after the equipment has been decontaminated. If the sampling order is changed and a pump must be decontaminated, a rinsate blank will also be taken at that time.

2.3.4 Sample Handling and Documentation

Samples obtained for volatile organic analyses will be collected in three 40-milliliter (ml) glass VOA vials with Teflon-lined caps, filled to the top with no headspace, and preserved with hydrochloric acid. Samples to be analyzed for major ion and trace metal analyses will be collected in one-liter glass or polyethylene bottles supplied by the laboratory with appropriate preservative. All samples will be stored on ice prior to and during shipment to the analytical laboratory.

2.3.5 Sample Containers and Preservation

Table 2.2 lists the analytes, containers, preservatives, storage requirements, and holding times for the groundwater samples to be collected from the monitoring wells and domestic wells. All samples will be taken using laboratory supplied new (unused) bottles. Any preservative will be added by the laboratory. Each preserved container will be clearly marked with the appropriate preservative by the laboratory. The laboratory will check the pH of preserved samples as they are submitted and adjust the pH as warranted.

2.3.6 Sample Identification

Collected samples will be labeled in water-proof ink with the following information:

- Field sample identification number.
- Date and time of collection.
- Initials of person collecting the sample.
- Other information pertinent to the sample.

Similar information is also entered on the chain-of-custody form, which will remain with the collected samples through delivery to the contract analytical laboratory.

2.3.7 Sample Packing and Transport

The following procedures are recommended when packing and transporting collected samples from the field to the analytical laboratory.

- Place a layer of plastic bubble wrap on the bottom and sides of a hard-sided ice chest.
- Package sample containers in individual re-sealable plastic bags and place in the ice chest.
- Package ice into two sealed plastic bags to prevent leakage and place ice packages around, among and on top of the packaged sample containers.
- Fill ice chest with cushioning material such as plastic bubble wrap.
- Place chain of custody form in a waterproof plastic bag and place on top of the cushioning material inside the ice chest.
- Secure the lid and drain plug of the ice chest with tape.
- Secure shipping label to top of ice chest with tape.

The cooler(s) containing the groundwater sample containers and chain of custody form(s) to the analytical laboratory should be transported so that the samples arrive prior to the shortest hold time expiring and prior to the ice melting. If applicable, the courier or persons (other than the sampler) involved with the delivery of samples to the analytical laboratory will be noted on the chain of custody form(s).

2.3.8 Chain of Custody Procedures

All necessary sample information will be transcribed to the chain of custody form. Each sampler will be responsible for updating his/her chain of custody form and for maintaining proper possession of his/her samples until they are relinquished. The chain of custody forms will be updated after each sample is procured. A sample is considered to be under a person's custody if:

- The sample is in the person's physical possession;
- The sample is in view of the person after that person has taken possession of the sample;
- The sample is secured by that person so that no individual can tamper with the sample;
- The sample is secured by that person in an area that is restricted to authorized personnel.

Completed chain of custody forms will be delivered with the samples to the appropriate contract analytical laboratory. Each chain of custody form must match the samples included in the associated cooler. The chain of custody forms will include the following information:

- Project name.
- Unique sample identification number.
- Sample collection date and time.
- Preservation method, if applicable.
- Analyses requested for each sample.
- Special handling or analysis requirements.
- Number and type of containers submitted.
- Field parameters including pH, specific conductance, and temperature.
- Dated signature of the person collecting the samples.
- Dated signature(s) of persons, other than the sampler, involved in the delivery of the samples to the contract analytical laboratory.

- Dated signature of the contract analytical laboratory acknowledging receipt of the collected samples.

The chain of custody form will be filled out and signed in blue or black indelible ink. A chain of custody form will be included with each cooler; the contents of the cooler will match that chain of custody form. The chain of custody tracking number and the date and time of delivery to the contract analytical laboratory will be noted in the Field Notebook. A copy of the chain of custody form will be delivered to and retained by the Contract Project Manager.

Prior to sealing a cooler with tape, the bottles in the cooler should be double-checked against that cooler’s chain of custody form.

3 QUALITY ASSURANCE PROJECT PLAN

3.1 DATA QUALITY OBJECTIVES

Data quality assurance begins in the field with the NAH Field QA/QC requirements. Field QC lists any field duplicate, replicate, and/or blanks that were collected and specifies any out of the ordinary characteristics such as relative percent differences (RPD)s over the specified limits.

Laboratory QC procedures follow field QC. Laboratory QC ensures holding times are met as per the Table 2.2, contaminants in any blank samples are accounted for, laboratory control samples and RPD's are within the control range, and calibration and tuning is done properly. Laboratory QC ensures that any problems with the sample analysis is accounted for.

Finally, the project manager must verify the legitimacy of the sample results and recommend any corrective actions to be taken.

Field measurement and sample collection will be conducted in accordance with established quality assurance procedures. These include the use of Standard Operating Procedures (SOPs), audits, and corrective action.

3.1.1 Standard Operating Procedures

Groundwater sampling SOPs (Appendix B) are detailed, written procedures that will be followed during the collection of field measurements and samples. The use of SOPs is meant to ensure consistency across multiple sampling events that may be conducted by different personnel.

3.1.2 Sample Analysis Validation

The type and reliability of methods used to analyze samples is very important in ensuring that the data are of a known and acceptable quality and that the data can be used for their intended purpose. The following sections describe the analytical methods that are likely to be used, and the standards and procedures that will be followed to ensure that data are acceptable.

3.1.3 Data Quality Objectives & Measurement Performance Criteria

The QAPP contains a discussion and summary of data quality objectives and measurement performance criteria for laboratory and field work. Specifically, these include precision, accuracy, comparability, and sensitivity of data. These are generally described below.

Precision refers to the degree to which repeated measurements are similar to one another. It measures the reproducibility among individual measurements, obtained under prescribed similar conditions. Measurements, which are precise, are in close agreement. The QAPP identifies the measurements that are precise as well as the formula used to determine precision. Precision is generally assessed by the measurement of sample duplicates, matrix spike/matrix spike duplicates (MS/MSD), and laboratory control sample/laboratory control sample duplicates (LCS/LCSD) relative percent differences (RPDs).

Accuracy is defined as the measurement of the closeness of an individual reading, or the average of a number of readings, to the true value. The accuracy measurement is generally determined by the percent recovery (%R) of a known value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations. The variance from the true value represents the bias associated with the accuracy.

Comparability is generally defined as a measure of the confidence with which one data set or method can be compared to another. Comparability of data is achieved by ensuring samples have been collected and analyzed following the same protocols.

Sensitivity is defined as the capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest. The QAPP includes a definition of method detection limits and reporting limits, and identifies how MDLs and Reporting Limits (RLs) have been determined.

3.1.4 Quality Assurance Procedures For Sample Analysis

The analysis of all samples will use USEPA-approved quality assurance procedures. These include the development and use of QAPPs, the collection and analysis of QA/QC samples, the performance of data validation, laboratory audits, and the development and implementation of corrective actions.

3.1.4.1 Collections/Analysis Of QA/QC Samples

The number of QA/QC samples to be collected during sampling will vary somewhat by how long the sampling takes. The purpose of these samples is to ensure that contamination of samples from external sources has not occurred and that samples are representative of the media that is being sampled. In general, duplicate samples will be collected at the rate of one for every ten primary samples or ten percent. One field blank will be collected at every twentieth well location. One equipment blank per day will be collected from each piece of sampling equipment after it has been decontaminated and before use for collection of samples. Ten percent of the samples will be subject to data validation; this requires a second set of bottles to be filled during sampling. All QA/QC samples will be sent “blind” to the lab meaning their sample identifications will be similar to the sample identifications for the actual groundwater samples.

3.2 DATA REDUCTION, VALIDATION AND REPORTING

The NAH QA/QC data validation requirement ensures that all samples are properly listed on the chain of custody (COC) and preserved as per Table 2.2. It will also ensure that all samples which have not been listed or tracked on the COC will be tracked for future validation. Validation also ensures that all sample labeled names coincide with the chain of custody names as well as field book notes. Data validation will be performed to verify whether an analytical method has been performed according to method and program specifications as specified in the QAPP. Data validation will involve reviewing the documentation, instrument output, and analytical reports associated with selected samples or groups of samples. Full validation will be conducted on 10 percent of the samples; the samples chosen for validation will be identified on the chains of custodies and extra bottles will be filled for these samples. Samples and analyses representative of the entire sampling effort, both detected and non-detected concentrations, will be included for validation. The analysis results will be verified for 100% of the samples.

Major Ions	Reporting Limit	Units	Methods
Chloride	0.2	mg/L	EPA 300.0
Fluoride	1	mg/L	EPA 300.0/325.2
Nitrite	0.1	mg/L	EPA 300.0
Bromide	0.2	mg/L	EPA 300.0
Nitrate	0.1	mg/L	EPA 300.0
Sulfate	5	mg/L	EPA 300.0
Carbonate	5	mg/L	EPA 310.1
Bicarbonate	5	mg/L	EPA 310.1
Alkalinity	5	mg/L	EPA 310.1
Sulfide	0.05	mg/L	EPA 376.2
Sodium	5	mg/L	EPA 200.7
Potassium	3	mg/L	EPA 200.7
Magnesium	0.2	mg/L	EPA 200.7
Calcium	0.2	mg/L	EPA 200.7
Metals	**Reporting Limit**	**Unit**	**Method**
Arsenic	2.5	μg/L	EPA 200.8
Barium	5	μg/L	EPA 200.8
Boron	5	μg/L	EPA 200.8
Cadmium	5	μg/L	EPA 200.7
Chromium	10	μg/L	EPA 200.7
Copper	2.5	μg/L	EPA 200.8
Iron	100	μg/L	EPA 200.8
Lead	1.5	μg/L	EPA 200.8
Manganese	5	μg/L	EPA 200.8
Selenium	4	μg/L	EPA 200.8
Silver	10	μg/L	EPA 200.7
Zinc	20	μg/L	EPA 200.7
Physical Properties	**Reporting Limit**	**Unit**	**Method**
pH	0.1	Standard Units	EPA 150.1
TDS (Total Dissolved Solids)	10	mg/L	EPA 160.1
TSS (Total Suspended Solids)	4	mg/L	EPA 160.2
Dissolved Gases	**Reporting Limit**	**Unit**	**Method**
Methane	5	μg/L	RSK SOP-175[a]
Ethane	5	μg/L	RSK SOP-175
Ethene	5	μg/L	RSK SOP-175
Hydrocarbons	**Reporting Limit**	**Unit**	**Method**
Diesel Range Organics	250	μg/L	SW846 8015B
Isotopes	**Reporting Limit**	**Unit**	**Method**
$\delta^{18}O$ (water)		‰	IRMS
δD (water)		‰	IRMS
$\delta^{13}C$ (dissolved gas)		‰	IRMS

Note: a) Concentration in water calculated based on partitioning from the aqueous into the gas phase in helium-filled headspace

Parameter	Method	Container	Lid	Preservation	Maximum Holding Times Extraction[a]	Analysis[b]
Metals (total)	200.7/200.8	500 ml polyethylene	Cap with Teflon® seal	HNO3 to pH<2; Ice to 4°C	-	6 months (Hg: 28 days)
Anions (Cl, F, Br, NO2-N, NO3-N, & SO4)	300.0	250 ml polyethylene	Teflon®-lined lids	Ice to 4°C	-	6 months (Hg: 28 days)
Alkalinity (CO3, HCO3, total)	310.1	250 ml polyethylene	Teflon®-lined lids	Ice to 4°C	-	14 days
Chloride	325.2	250 ml polyethylene	Teflon®-lined lids	none	-	28 days
Sulfide	376.2	500 ml polyethylene	Cap with Teflon® seal	ZnAc/NaOH to pH>9; Ice to 4°C	-	7 days
pH	150.1	250 ml polyethylene	Teflon®-lined caps	none	-	immediate
Specific conductance	120.1	250 ml polyethylene	Teflon®-lined caps	Ice to 4°C	-	28 days
Total Dissolved Solids	160.1	500 ml polyethylene	Cap with Teflon® seal	Ice to 4°C	-	7 days
Total Suspended Solids	160.2	500 ml polyethylene	Cap with Teflon® seal	Ice to 4°C	-	7 days
Dissolved gases	RSK SOP-175	40 ml glass vials X 3	Cap with Teflon® septum	H2SO4 to pH<2; Ice to 4°C		14 days
Volatile organics (BTEX)	8021B	40 ml glass vials X 3	Cap with Teflon® septum	HCl to pH<2; Ice to 4°C	-	14 days
Diesel Range Organics	8015B	40 ml glass vials X 3	Cap with Teflon® septum	HCl to pH<2; Ice to 4°C		14 days

Abbreviations: a = Starting from the date of collection
ml = milliliter b = Starting from the date of extraction; if no extraction is involved, starting from the date of collection
oz = ounce c = Extraction may occur any time prior to analysis. Only the analysis holding time is monitored.

Sources: 1) Methods for Chemical Analysis of Water and Wastes, U.S. EPA-600/4-79-020, March 1983
2) Routine Containers, Preservation, and Hold Times for Drinking Water-In-House Parameters, Severn Trent Laboratories, 2006
3) Analysis of Dissolve Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique, Journal of Chromatographic Science, May 1998

APPENDIX A
GENERAL WELL CONSTRUCTION, CONDITION, AND USE FORM EXAMPLE

PERMITTED WATER WELLS

Well Name	Contact Name	Contact Phone	Sampling Date	GPS N	GPS W	Legal	Permit#	Casing and wellhead construction material (PVC, black iron, etc.)	Sanitary seal (condition, access for water level measurement)	Ability to measure a static water level	Well Depth Ft	Depth to GL (ft)	Static Depth Ft
Well XYZ #1	Landowner 1	685-5689	1/18/2003	44.34435	-105.89125	SE NE S05 T54N R075W	P142588W	Steel 5 1/2" 940'	Yes plate at 2'	No could get down	940	10"	NA

PERMITTED WATER WELLS

Well Name	Ability to measure any methane gas build-up at the wellhead	Methane Lv.	Hydrogen Sulfide Lv.	Ventilation Status of Well Housing	General condition of the well (corrosion, wellhead seal, annular seal)	Location with respect to surface influences (septic tanks, drainages, ponds, etc.)	Historical use	Current use	Pumping rate when operational	Typical pumping cycle
Well XYZ #1	No	NA		Open no house	Good leak in vault	None away from house	Domestic no yard	Domestic	5gpm	Household only

PERMITTED WATER WELLS

Well Name	Typical average monthly withdrawal and seasonal variation	Age or date of construction (from log or owner)	Screen type (from log or owner)	Completion zone (from log or owner)	Pumping equipment (type, depth setting, previous problems, etc.)	Ability to measure pumping rate (use existing flow meter or retrofit to allow bypass to portable flow meter)	Ability to take water sample (prior to water entering a tank or any treatment system)
Well XYZ #1	5,000 gal per month	1965 Feb 27	unknown	10 perf 873' to 883' & 892' to 902	Sta-Rite L10P4 Submersible	No	Yes hose bib in vault

APPENDIX B
STANDARD OPERATING PROCEDURES (SOPs) FOR WELL SAMPLING

Groundwater Sample Collection

Norwest Applied Hydrology
Standard Operating Procedure

November 29, 2006

GROUNDWATER SAMPLE COLLECTION

TABLE OF CONTENTS

1.0 OBJECTIVES

The primary objective of this standard operating procedure (SOP) is to establish a uniform method for the collection of representative groundwater samples from monitoring wells, and to reduce the potential variability associated with purging and sampling.

2.0 SCOPE AND APPLICABILITY

This SOP will be used to support groundwater monitoring programs and conducting the field groundwater sampling activities. Groundwater sampling involves two primary operations, purging stagnant water from a well followed by the collection of a sample from the same well. Groundwater sampling variables can be significantly controlled through the appropriate selection and use of purging and sampling equipment, and through the use of procedures that are described in this SOP.

3.0 REQUIRED MATERIALS

Materials required for conducting groundwater sampling are variable depending upon the method chosen to conduct the sampling. Therefore the listing of materials will be separated into two parts in this SOP. This section will present materials that are general in applicability – things that should be included regardless of purge or sampling method. In Section 5, where specific methods and approaches are discussed, additional materials will be listed. General materials that should be considered regardless of method are as follows:

- Personal protection equipment (as required by the Site Health and Safety Plan)
- Health and safety monitoring equipment (e.g., PID)
- Well Completion Forms and Data from previous sampling efforts (if available)
- Water level indicator
- Decontamination supplies (5 gallon buckets, decontamination fluids, squirt bottles)
- Water quality monitoring equipment
- Purge pumps and control boxes
- Generator
- Compressed nitrogen bottles
- Permanent marking pens
- Notebook
- Calculator
- Measuring tape
- Investigation derived waste (IDW) containers and labels
- Garbage bags
- Shipping labels and Chain of Custody records
- Shipping coolers and ice
- Filters (0.45 µm), if appropriate
- Tubing

4.0 RESPONSIBILITIES

The *Project Manager*, or designee, will have the responsibility to oversee and ensure that groundwater purging and sampling procedures are implemented in accordance this SOP and any project- or site-specific planning documents.

The *field personnel* will be responsible for the understanding and implementation of this SOP during groundwater sampling activities, as well as, obtaining the appropriate field logbooks, forms and records necessary to complete the field activities.

5.0 METHODS

5.1 General Considerations

Groundwater sampling involves two primary operations. These include the purging of stagnant water from the well followed by the collection of a sample. Groundwater sampling variables can be significantly controlled through the appropriate selection and use of purging and sampling equipment, and through the use of procedures that are described below.

Good communication is essential to the ultimate success of a groundwater sampling project. This includes communication within the project team, as well as communication with the client and analytical laboratory, when establishing project objectives.

Good communication with the project team, laboratory, client, and, if appropriate, regulatory agencies, includes complete project specific planning documents such as field sampling plans, quality assurance plans, and scope of work documents for subcontracted laboratories. Plans should include detailed information with respect to site-specific requirements, with reference to SOPs wherever possible, and risk criteria that will be used to assess the data. The quality assurance plan and laboratory scope of work (of which the quality assurance plan can be part) should contain detailed information regarding what is expected from the laboratory regarding the methods to be used, quality assurance measures and calibrating corrective measures, and deliverables (especially electronic deliverable formats).

In addition to good communication, the project plans should consider equipment decontamination, sampling equipment, sampling sequence, and field quality assurance/quality control (QA/QC) samples. These are described in the following sections.

5.1.1 Equipment Decontamination

Equipment that will be in contact with the sample must be decontaminated prior to or after each use. This is necessary to minimize inadvertent contamination of the sample. Specific methods for equipment cleaning are dependent upon a number of factors including the sample media, analytical parameters, the purpose of the investigation, the equipment to be cleaned, and the specific regulatory guidelines that may apply.

Any site specific decontamination procedures can be specified in the field sampling plan for each project.

5.1.2 Dedicated and Disposable Equipment

Use of dedicated and new, disposable purging and sampling equipment are preferable to decontamination of reusable sampling equipment. Dedicated equipment, and use of new, disposable equipment, can virtually eliminate cross-contamination between samples caused by incomplete decontamination. Dedicated equipment can also increase sampling efficiency through the elimination of the need to decontaminate equipment for successive sampling. Furthermore, dedicated equipment can also help to reduce the physical handling of the equipment that can cause sample contamination through contact with potentially contaminated surfaces. New, disposable equipment may need to be decontaminated before use. Review project-specific planning documents regarding decontamination of disposable equipment.

5.1.3 Sequence of Sampling

The groundwater sampling operation should always be conducted in a sequence that proceeds from wells containing the lowest concentrations to wells containing the highest concentrations. Sampling in this order will further minimize the likelihood of sample cross-contamination that can be caused through improper handling or equipment cleaning. This type of sampling sequence should be used even for programs in which equipment is dedicated to minimize the cross-contamination that could result from exposure to contaminated garments or other equipment. If water quality is not known, the wells up-gradient of a suspected source area should be sampled first, followed by the wells furthest away and cross-gradient or down-gradient.

Sampling sequence also applies to the order that different analytes are collected. Typically these analytes that are volatile are collected first, followed by those that are sensitive to oxidation.

5.2 Purging And Sampling Procedures

This section provides a description of the procedures to be used for groundwater sampling. These procedures include planning, preparatory office activities, preparatory field activities, well purging, well sampling, and post sampling activities. These activities are listed on Attachment A and are described in detail in the following sections. Many of these steps have record keeping components which are discussed in Section 5.3.

5.2.1 Planning

The planning phase should include the selection of specific field methods, including the well purging strategy and planning for the proper disposal of the purge water. The sampling program should be discussed in project-specific planning documents.

Good communication with the analytical laboratory is essential to the success of a groundwater sampling project. The analytical requirements must be well defined and clearly communicated, prior to conducting the field work. Written communication is encouraged, in particular to document requirements for specific analytical methods, low detection limits, and other special needs. Written communication should include a detailed scope of work that includes the quality assurance plan for the project. These plans should specifically identify detection limits, with particular emphasis placed on how these limits relate to regulatory criteria or risk based criteria that have been developed for the project.

Purging and Sampling Equipment Selection

Some of the factors that should be considered in the selection of purging and sampling devices include:

- Well yield
- Depth to water
- Well diameter and depth
- Required material of construction
- Analytical parameters
- Regulatory requirements
- Cost

Purging Strategies

The strategy that will be employed for well purging should be determined prior to sampling and presented in project-specific planning documents. Several different strategies are commonly used in order to assess the completeness of well purging. The most common purging strategies are listed below.

- Purging is continued until stabilization of certain indicator parameters is observed in successive measurements over a specified time or volume. The most commonly used indicator parameters include pH, specific conductivity, turbidity, temperature, oxidation/reduction potential (ORP), and dissolved oxygen (DO).
- Purging 3 to 5 well volumes of water from the well.
- Purging low yield wells until the water level reaches the top of the well screen, and then allowing the well to partially recover. After partial recovery, the well is re-purged to the top of the well screen and allowing the well to partially recover a second time. It is recognized, however, that it may not be possible to avoid dewatering the well screen in many shallow wells.
- Very low yield wells are purged until dryness and allowing the well to partially recover (often 12 to 24 hours).
- Low or no-flow purging strategies. Generally, well is pumped at rates (<0.5 gallons per minute) that do not induce drawdown and ostensibly mirror flow rates in the aquifer. These are gaining acceptance in many areas because such techniques reduce generated wastes. Often regulatory agencies will require a comparison study before acceptance but these can be valuable when long term monitoring programs will be implemented.
- Domestic wells should be purged by opening the spigot and allowing a pre-determined amount of water (e.g., 20 gallons) to flow through. Purging is then continued until indicator parameters have stabilized.

Implementation of these strategies is discussed in more detail in Section 5.2.

Purge Water Disposal

The methods and responsibility for collection, containerization, treatment and disposal of purge water should be determined prior to initiation of any sampling project. However, additional considerations for groundwater purging and sampling are included below.

Collection and containment is often accomplished through use of 55 gallon drums, mobile storage tanks, or through use of vacuum trucks which can directly transport to a treatment facility or to an evaporation pond on site. If specifically allowed by the responsible agency, purge water may be reapplied to the ground surface. Treatment of purge water may be accomplished on site at facilities that have wastewater treatment plants, or by using a mobile treatment unit. Responsibility for off-site disposal of containerized purge water must be determined prior to conducting the work.

5.2.2 Preparatory Office Activities

Equipment and containers should be organized in the office prior to embarking on a field sampling project to the extent practicable. The time spent in the field should be spent on sample collection, making field measurements and recording data.

Prepare Sampling and Purging Equipment

The purging and sample collection equipment and all required hardware should be obtained, organized and decontaminated prior to the initiation of the field sampling program. To accommodate waste generated during decontamination, these activities may be completed at the site prior to sampling.

Sample Containers and Preservatives

The appropriate sample containers and associated preservatives must be obtained. The containers and preservatives are normally, but not always, supplied by the laboratory that will be responsible for the analyses. Sample containers should be organized and inventoried several days prior to initiation of the sampling program in order to provide sufficient time to rectify any problems, should they occur. Whenever possible, pre-printed sample labels should be created prior to mobilization, if possible.

Initiation of Field Data Records

Field data sheets should be initiated prior to the start of sampling. Examples of initial data to be recorded include site and sampling location identification, well depth and construction, and purging and sampling collection methods. Additional discussion regarding field records is presented in Section 5.3. Example field data sheets are provided in Attachment A. These sheets can be combined in a bound field notebook as well.

5.2.3 Preparatory Field Activities

The following procedures should be conducted in the field prior to well purging and sampling.

Well Maintenance Check

A well maintenance check should be performed that includes a visual inspection of the condition of the protective casing and surface seal. In addition, the well should be inspected for other signs of damage or unauthorized entry. Any problems should be documented.

It is recommended that the bottom of the well not be sounded each time the well is sampled. Routine sounding of the well can increase the risk of inadvertent well contamination because it is difficult to adequately decontaminate the tapes used for this purpose. Well depths obtained from well completion records are generally adequate for the purpose of the determination of well volume. Generally, the only reason to sound well depth is if a need to verify the depth arises, or if you suspect that sediment/soil has collected in the bottom of the well.

Preparation of Well Area

A suitable work area should be established around the perimeter of the well. Sampling equipment should be placed on a clean surface such that it will not become inadvertently contaminated. This work area can be prepared by placing new polyethylene (PE) sheeting on the ground around the well, taking care not to step on it. Alternatives also include the placement of a clean PE-lined trash can, a clean PE or aluminum covered table, or similar, adjacent to the well. Remember – a clean work area leaves a much more favorable impression than a dirty work area.

Water Level Measurements

The depth to water should be measured prior to initiation of all sampling activities. The water level measurements should be made from the same marked point on the inner well casing each time.

Calculation of Well Purge Volume

The volume of water standing in the well should be calculated through the application of the depth to water data, the known well depth, and the well diameter using the constants presented below. Well depth information obtained from the well completion records are generally sufficiently precise for the purpose of well volume calculations that would be used for subsequent purging determinations.

The following conversions allow quick calculation of well casing volumes:

Well Casing Diameter (inches)	Gallons per foot of water
1.0	0.041
2.0	0.163
3.0	0.367
4.0	0.653
6.0	1.469

Alternatively, the well casing volume may be calculated using the formula $V = CF{*}d^2h$, where

$V =$ volume of water (gallons)

$d =$ diameter of well (inches)

$h =$ height of water column (feet)

$CF =$ conversion factor (0.0408) that includes conversion of cubic feet to gallons, inches to feet, and diameter to radius.

In some states the volume of the entire well (not just the well casing, but entire borehole) is required when determining well volume. Check local state requirements to determine which method of well volume calculation applies to your site. This volume can be calculated in a manner similar to above with the following formula:

$$V = 0.0408\, d^2h + 0.0408\, (D^2 - d^2)\, h\varnothing$$

where:

V = volume of water in well (gallons)

D = diameter of borehole (inches)

d = diameter of well casing (inches)

h = height of water column (feet)

$\varnothing$ = porosity of sand pack (often approximated at 0.30)

Which of the above methods should be used should be discussed or defined in the project-specific planning documents.

Land Owner Notification and Communication

For domestic wells or monitoring wells that are located on property not owned by the client, landowners must be notified prior to sampling. The notification should be at least several days prior to the sampling event and should include the specific date and times that personnel will be on the property. Coordination as to who will contact the landowner should be done in advance. It should also be determined if a written agreement (e.g., a right-of-entry) between the client and the landowner prior to accessing the property is required. You may discuss the sampling procedure with the landowner, but do not discuss water quality results – especially their neighbor's water quality results. Do not offer any opinions about the site in your conversation with the landowner. The client has a fact sheet that lists what facts may be discussed with landowners; any topics not included on the fact sheet should be avoided. You may give the landowner the client's phone number and advise him to contact the client for more information.

5.2.4 Well Purging

Monitoring wells and domestic wells must be purged prior to the collection of aqueous phase samples. Specific instructions for the use of purging equipment are presented in Section 5.2.6.

The placement of a device (in most cases a pump) that will be used for well purging is critical in order to ensure a complete exchange of the entire water column. The intake of a device used for purging should be placed as high in the water column as is possible under pumping conditions. Optimum placement is to have the pump at the top of the water column. This is done so that purging will draw water from the formation into the screened area of the well, and up through the casing, so that the entire static water column can be removed. In monitoring wells, there is the flexibility to raise or lower the pump in the well to achieve optimum placement. In a domestic well, this is not the case because the well pump is fixed inside the casing to the surface making changes to the configuration infeasible.

If the monitoring well is a slow recharging well, then the pump should be placed near the surface and slowly lowered at a rate similar to groundwater withdrawal. As an alternative approach the pump could be set at no more than three to five feet below the water surface. If the recovery rate of the well is faster than the pump rate and no observable drawdown occurs, the pump can be raised until the intake is within one foot of the top of the water column for the duration of purging. If the pump rate exceeds the well recovery rate, the pump will have to be lowered as needed based upon the amount of drawdown.

Standard Purging Approach

Initially, groundwater withdrawal should occur no more than three to five feet below the water surface. If the recovery rate of the well is faster than the pump rate and no observable drawdown occurs, the pump should be raised until the intake is within one foot of the top of the water column for the duration of purging. If the pump rate exceeds the well recovery rate, the pump will have to be lowered as needed based upon the amount of drawdown.

An adequate purge is normally achieved when three to five times the volume of standing water in the well has been removed. After three well volumes have been removed, if the chemical parameters have not stabilized according to the criteria given below, additional well volumes may be removed. If the parameters have not stabilized within five volumes, it is at the discretion of the project manager whether or not to collect a sample or to continue purging. If a sample is taken after five volumes and the field parameters have not stabilized, this situation will be noted in the field book.

Considering groundwater chemistry, an adequate purge is achieved when the pH, specific conductance, and temperature of the groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs). In very silty formations, the turbidity stabilization criteria given above may be impossible to reach and should be disregarded. Other parameters such as salinity, dissolved oxygen, and oxidation reduction potential also may be important criteria for stabilization, especially under low flow purging. Stabilization occurs when parameter measurements are within 10 percent between two readings spaced approximately one well volume apart, or under low flow purging, between two readings determined in project planning documents. A water meter quality fitted with flow through cell, which allows continuous monitoring of the above parameters is recommended for these measurements.

Attempts should be made to avoid purging wells to dryness, as previously described. However, even with slow purge rates, a well may be purged dry. In those cases, this constitutes an adequate purge and the well can be sampled when recovery is sufficient (enough volume to fill the sample containers). Recovery criteria are often cited as 80 percent of the original well column height. The maximum recovery time prior to sampling should be 24 hours.

Low Stress or Low Flow Groundwater Purging

Sometimes it is desirable to collect representative samples while exerting minimum stress on the water-bearing formation. Typically this is accomplished by limiting the flow rate during purging to the range of 100 to 500 ml/min (0.025 to 0.13 gallons/min). For this procedure, the goal is to induce a steady flow rate while minimizing the drawdown.

It is important to insert the sampling equipment carefully, so as to prevent the re-suspension of silt and clay particles in the well. In order to minimize turbidity, it is preferable to use dedicated equipment, or to allow sufficient time after the installation of non-dedicated equipment to allow soil particles to re-settle before purging and sampling. Sufficient time for settling should be verified by turbidity measurements.

Initially, the purge flow rate should start at approximately 200 ml/min (0.053 gallons/min), and water level should be frequently monitored. Flow rate should be adjusted so that drawdown will not exceed 0.3 ft, or approximately 2 percent of the saturated thickness of low permeability formations, whichever is greater.

Indicator parameters which should be monitored for low stress groundwater purging include turbidity, specific conductance, temperature, pH, ORP, and DO. In-line analyzers and continuous readout displays are recommended, so that the sample is not exposed to air prior to measurement. The well is considered stabilized when three consecutive readings vary no more than 10% or are below 10 NTUs for turbidity, 3% for specific conductance, 0.1 SU for pH, 10 mV for ORP, and 10% for DO. Measurement of the indicator parameters should continue every three to five minutes until these measurements indicate stability in the water quality. If these parameters have not stabilized after about an hour, the sample will be collected and a note will be made in the field book.

Domestic Well Purging

Domestic wells should be purged by opening the spigot and allowing a pre-determined amount of water (e.g., 20 gallons) to flow through. Purging is then continued until indicator parameters such as pH, specific conductance, and temperature have stabilized.

5.2.5 Groundwater Sampling

It is important that wells be sampled as soon as possible after purging. If adequate volume is available, the well should be sampled immediately as long as the well has recovered to 80 percent of the original water column height. If not, sampling should occur as soon as the well has recovered sufficiently to provide adequate volume. Specific instructions for the use of sampling equipment are presented in Section 5.2.6.

Standard Sampling Approach

As with purging equipment, there are a number of considerations in the selection of sample collection equipment. Furthermore, it is common to use a different device for sample collection than for purging. An example would be to purge with the use of submersible pump and to collect the sample with the use of a disposable bailer.

As discussed previously, consideration should be given to the order in which sample containers are to be filled for various parameter groups. The order should be determined on the basis of parameter sensitivity to volatilization, pH change, or oxidation, and the priority for analytical data in cases where the water volume in the well is less than what is required for analysis. In general, volatile organic compounds are the most sensitive constituents to volatilization so the sample for these parameters should be containerized immediately. Likewise, pH change occurs rapidly in samples that are in contact with air, so pH measurements and the containerization of pH sensitive parameters, such as anions (e.g., nitrate, sulfate), or metals, (e.g., ferrous iron or Fe2+), should also be implemented expeditiously.

Low Stress Groundwater Sampling

Sometimes it is desirable to collect representative samples while exerting minimum stress on the water-bearing formation. Typically this is accomplished by limiting the flow rate during sampling to the range of 100 to 250 ml/min (0.025 to 0.065 gallons/min). Sampling flow rate should not exceed the purge flow rate for which water quality indicator parameters stabilized. Sampling equipment must be the same equipment that was used for purging, and should not be moved between purging and sampling activities.

Domestic Well Sampling

Sampling a domestic well requires minimal equipment since the domestic water supply system includes a pump and pressurization tank that delivers a reliable sample stream under pressure. Domestic well samples should be taken prior to in-line water filters or water softeners. Garden hoses should be removed prior to sampling.

5.2.6 Equipment Instructions

This section provides specific instructions for the installation and use of various devices for both well purging and groundwater sample collection, and includes the following equipment. The information is summarized in Attachemnt B.

A. Bailer
B. Bladder pump
C. Small diameter (2-inch) electric submersible pump
D. Large diameter (4-inch) electric submersible pump
E. Compressed gas-driven piston pump
F. Gasoline powered centrifugal pump
G. Peristaltic suction pump
H. Inertial lift pump
I. Domestic water supply system.

It is recognized that a combination of the procedures may be employed. An example would be the use of a small diameter electric submersible pump for purging and a bailer for sample collection. The specific methods to be used for purging and sampling a well should be outlined in the project-specific planning documents. A matrix to aid in selection of the appropriate equipment is included in Attachment C.

A. Bailer

A bailer is one of the simplest groundwater sampling devices. The same bailer can be used for both purging and sample collection. Bailers consist of a rigid tube equipped with a bottom and/or top check valve that is lowered into the well on a flexible cord.

Required Equipment:

- Bailer of appropriate size and material
- New bailer cord of appropriate material
- New disposable gloves of appropriate material
- Clean trash can and supply of trash can liners, or new plastic sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Bottom emptying device (optional)
- Water quality monitoring equipment

Purging Instructions:

1) Determine the volume of water to be purged, as described previously.
2) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
3) Don a new pair of gloves. Decontaminate equipment thoroughly
4) Attach a cord to the bailer.
5) Lower the bailer into the well until it is completely submerged. The bailer should be lowered slowly so that it does not cause a splash that could aerate the water column.
6) Pull the bailer out of the well while placing the cord on the PE sheet or in a PE-lined bucket. An alternate method is to wind the bailer cord between the hands. Care should be taken to prevent the bailer or the cord from contacting any surface other than the interior of the well or the plastic liner.
7) Empty the bailer into the pail.
8) Repeat the operation until the necessary volume of water has been purged from the well.
9) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Prepare the well area and lower the bailer into the well following the method described previously for purging.

2) Allow the bailer to fill slowly and then gently retrieve the bailer from the well while avoiding contact with the sides of the well. Care should be taken to prevent the bailer or the line from contacting any surface other than the interior of the well or the PE sheet or PE-lined bucket.

3) Fill the sample containers slowly. The use of a bottom emptying device is preferred in that sample aeration and sample volume loss are minimized.

4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

5) Filtered samples can be obtained by filling a non-preserved sample receptacle, and then transferring the liquid through an in-line filter (typically a 0.45 µm disposable filter) into a preserved sample receptacle using a peristaltic pump. Other gravity feed filters also are available.

B. Bladder Pump

A bladder pump is one of the easiest devices to operate for the purpose of purging and sample collection. The bladder pump is often dedicated to the well and can be used in conjunction with an inflatable packer in order to minimize the purge volume necessary to accomplish effective purging.

Required Equipment:

- Bladder pump
- Tubing of appropriate type and length
- Bladder pump controller
- Compressed inert air source
- New disposable gloves of appropriate material
- New plastic sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions (initial installation or non-dedicated use):

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Assemble the pump and tubing and lower into the well being careful not to contact any surface other than the interior of the well or the plastic sheeting.
4) Decontaminate equipment and pump (if not dedicated) as outlined in decontamination SOP
5) Install the air inlet and water discharge fittings on top of the well (for a dedicated installation).

Purging Instructions:

1) Refuel the gasoline-powered compressor, if used, at a location that is remote from the well, being very careful not to spill any fuel on equipment or clothing that will be used at the well site.
2) Place the gasoline-powered compressor as far from the well as possible in a down-wind direction to eliminate potential exhaust impact to sampling.
3) Connect the compressed air source and pump controller to the pump as per manufacturer's instructions.
4) Don a new pair of gloves after handling the gasoline-powered compressor.
5) Determine the volume of water to be purged, as described previously.
6) Start the pump by opening the regulator on the controller, which allows compressed air to flow into the system.
7) The controller should be adjusted to maximize the flow rate while minimizing the rapid "jolting" of the tubing as water is drawn into pump.
8) Direct the pump discharge to the five gallon pail and determine the pumping rate.
9) Continue pumping until the necessary volume of water has been purged from the well.
10) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.
2) Resume pumping after adjusting the regulator to the minimum pressure that will still allow water to be pumped to the surface.
3) Collect the samples by pumping directly into each of the required containers.
4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge.

C. Small Diameter (2") Electric Submersible Pump

A small-diameter electric submersible pump (Grundfos Redi-Flo2 or equivalent) can be operated with a wide variety of pumping rates such that it is very versatile for both well purging and sample collection. This type of pump can be used in either a dedicated or non-dedicated mode. Collecting groundwater samples from these pumps is only appropriate if approved project-specific planning documents specifically include this technique for collecting samples.

Required Equipment:

- Small diameter electric submersible pump
- Pump shroud (when used in a six-inch or larger well to minimize turbulence, to keep motor cool)
- Teflon® jacketed power cable on a plastic reel
- Tubing of appropriate type and length
- Check valve (optional)
- Electric pump controller with appropriate power plug
- 230 volt, single phase, electric power source, >10 amps
- Tool kit including basic tools, tubing cutters, extra tubing connector bracket, electrical connectors, wire ties, etc.
- Ground fault interrupter (GFI)
- New disposable gloves of appropriate material
- New PE sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Assemble the pump, tubing, optional check valve, and electric power cables.
4) Decontaminate equipment and pump (if not dedicated) as outlined in decontamination SOP.
5) Prime pump with deionized water by inverting the pump and removing fill cap.
6) Lower pump slowly into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting. When lowering the pump be particularly sensitive to areas that suggest drag or problems in the well where the pump could get

stuck. If a problem exists do not continue, but discuss ways to investigate with PM or senior technical personnel.

7) Place the pump intake as discussed in Section 5.4.2. Monitor the pump discharge and well hydraulics as discussed previously.

Purging Instructions:

1) Refuel the electric generator at a location that is remote from the well, being very careful not to spill any fuel on equipment or clothing that will be used at the well site.
2) Place the gasoline-powered compressor as far from the well as possible in a down-wind direction to eliminate potential exhaust impact to sampling.
3) Don a new pair of gloves after handling the generator.
4) Connect electric power, GFI, and pump controller to the pump.
5) Determine the volume of water to be purged, as described previoulsy.
6) Start the pump.
7) Direct the pump discharge to the five gallon pail and determine the pumping rate.
8) Continue pumping until the necessary volume of water has been purged from the well.
9) If the pump intake has been placed deeply down into the water column for some reason, slowly withdraw the pump upward through the water column while it is still running to purge all water standing above the pump unless the pump will be used for sample collection.
10) Shut off the pump rapidly whenever the pump stops pumping water.
11) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.
2) Resume pumping and adjust the pumping rate to the slowest possible rate, if necessary.
3) Collect the samples by pumping directly into each of the required containers.
4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).
5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge.

D. Large Diameter (4") Electric Submersible Pump

A large-diameter electric submersible pump is most frequently used for purging large-diameter wells that cannot be efficiently purged using other methods. Large-diameter pumps can also be used for sample collection for parameters that are not particularly pH or pressure sensitive. This type of pump is usually not dedicated. Collecting groundwater samples from these pumps is only appropriate if approved project-specific planning documents specifically include this technique for collecting samples.

Required Equipment:

- Large-diameter, stainless steel electric submersible pump
- [Optional] Check valve, install internally within the pump or externally between the pump and the tubing
- Electric power cable on a plastic reel (Teflon® jacketed cable is preferred)
- Stainless steel or polypropylene support line
- 1/2" to 1" PE Tubing of appropriate length
- Flow control valve
- 120 or 240 volt electric power source (as appropriate)
- Ground fault interrupter (GFI)
- Tool kit including assorted basic tools, tubing cutters, wire cutters, hose clamps, waterproof connectors, wire ties, hose fittings, assorted pipe nipples and adapters, etc.
- New disposable gloves of appropriate material
- New plastic sheeting
- Five gallon pail, graduated in minimum one gallon increments or flow meter
- Bleeder tee (if the submersible pump is used for sample collection). This consists of a tee with a large diameter, valved pump discharge port and a Water quality monitoring equipment.
- small diameter, valved port equipped with a sample weephole.
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Decontaminate equipment and pump (if not dedicated) as outlined in decontamination SOP.
4) Assemble the pump, tubing, flow control valve, electric power cables and support line and lower into well being careful not to contact any surface other than the interior of the well or the PE sheeting.
5) The tubing, electrical power cable and support line should be fastened together at 15 to 20 foot intervals with the use of nylon wire ties taking care to leave adequate slack in the electric power cable. Electrical tape is not preferred but can be used to secure the lines if the sample is not being analyzed for VOCs.

6) The use of a check valve is recommended to prevent rapid backflow of water from the tubing after the pump is shut off. It is recognized, however, that the use of a check valve makes it more difficult to pull the pump from the well due to the added weight of the water in the tubing and can increase the chance of "sand locking" occurring in the pump.

7) Lower pump slowly into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting. When lowering the pump be particularly sensitive to areas that suggest drag or problems in the well where the pump could get stuck. If a problem exists do not continue, but discuss ways to investigate with PM or senior technical personnel.

8) Place the pump intake as discussed in Section 5.4.2. Monitor the pump discharge and well hydraulics as discussed previously.

Purging Instructions:

1) Refuel the electric generator at a location that is remote from the well, being very careful not to spill any fuel on equipment or clothing that will be used at the well site.

2) Place the gasoline-powered compressor as far from the well as possible in a down-wind direction to eliminate potential exhaust impact to sampling.

3) Don a new pair of gloves after handling the generator.

4) Connect electric power and GFI to the pump.

5) Determine the volume of water to be purged, as described previously.

6) Start the pump.

7) Determine the pumping rate either by directing the pump discharge to the five gallon pail or with the use of a flow meter.

8) Adjust pumping rate to match the yield of the well.

9) Continue pumping until the necessary volume of water has been purged from the well.

10) If the pump intake has been placed deeply down into the water column for some reason, slowly withdraw the pump upward through the water column while it is still running to purge all water standing above the pump.

11) Shut off the pump immediately whenever the pump stops pumping water.

12) Dispose of the tubing and support line after use.

13) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.

2) Resume pumping and adjust the bleeder tee valves so that a slow, steady, non-aerated flow emanates from the bleeder tee weephole (approximately 100 ml/min).

3) Collect the samples directly from the weephole into each of the required containers.

4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials.

Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge

E. Compressed Gas-Driven Piston Pump

A compressed gas-driven piston pump can be used for purging and sample collection in two-inch diameter wells at great depths. This type of pump is not typically dedicated. Collecting groundwater samples from these pumps is only appropriate if approved project-specific planning documents specifically include this technique for collecting samples

Required Equipment:

- Small diameter air driven pump
- Tubing of appropriate type and length
- Pump controller
- Compressed air source
- New disposable gloves of appropriate material
- New plastic sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Decontaminate equipment and pump (if not dedicated).
4) Assemble the pump and tubing and lower into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting.
5) Lower pump slowly into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting. When lowering the pump be particularly sensitive to areas that suggest drag or problems in the well where the pump could get stuck. If a problem exists do not continue, but discuss ways to investigate with PM or senior technical personnel.
6) Place the pump intake as discussed in Section 5.4.2. Monitor the pump discharge and well hydraulics as discussed previously.

Purging Instructions:

1) Connect the air source and pump controller to the pump.

2) Determine the volume of water to be purged, as described above.

3) Start the pump.

4) Direct the pump discharge to the five gallon pail and determine the pumping rate.

5) Continue pumping until the necessary volume of water has been purged from the well.

6) If the pump intake has been placed deeply down into the water column for some reason, slowly withdraw the pump upward through the water column while it is still running to purge all water standing above the pump.

7) Shut off the pump immediately whenever pump stops pumping water.

8) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.

2) Resume pumping and adjust to a slow pumping rate (approximately 100 ml/min).

3) Collect the samples by pumping directly into each of the required containers.

4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge.

F. Gasoline Powered Centrifugal Suction Pump

A two-cycle gasoline-engine-powered centrifugal pump provides an effective way to rapidly purge any well in which the depth to the pumped water level is less than about 20 to 25 feet. This type of pump is normally used with dedicated tubing. Groundwater sampling cannot be conducted using these pumps.

Required Equipment:

- Two-cycle gasoline-engine-powered centrifugal pump
- 1/2" to 3/4" PE tubing of appropriate length
- Flow control valve and check (foot) valve
- Supply of distilled or deionized water
- New disposable gloves of appropriate material
- New PE sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Water quality monitoring equipment

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Decontaminate equipment such as hose (if not dedicated).
4) A check valve should be installed on the bottom of the tubing in order to prevent backflow of water into the well from the tubing and the pump after the pump is shut off. The check valve will also aid in priming the pump.
5) Lower the tubing into well, being careful not to contact any surface other than the interior of the well or the PE sheeting. The outside of the tubing should be decontaminated.
6) Place the intake of the tubing as high in the well as is possible but deep enough that it will not break suction.

Purging Instructions:

1) Refuel the pump at a location that is remote from the well, being very careful not to spill any fuel on equipment or clothing that will be used at the well site. Pay strict attention to the required fuel mixture (gasoline/oil) that is specified by the pump manufacturer.
2) Place the gasoline-powered compressor as far from the well as possible in a down-wind direction to eliminate potential exhaust impact to sampling.
3) Connect the tubing to the pump.
4) Don a new pair of gloves after handling the pump.
5) Determine the volume of water to be purged, as described previously.
6) Prime the pump using either distilled, deionized, or potable water. Use potable water only if the source has been tested analytically and found to be clear of the constituents of interest. Alternately, a pump equipped with a check valve on the tubing can be primed by working the tubing in an up and down motion, as with the inertial lift pump. This second approach should only be used if no other alternative is available for priming the pump.
7) Start the pump.
8) Direct the pump discharge to the five gallon pail and determine the pumping rate.
9) Adjust the pumping rate to match the yield of the well.
10) Continue pumping until the necessary volume of water has been purged from the well.
11) If the pump intake tubing has been placed deeply down into the water column for some reason, slowly withdraw the tubing upward through the water column while it is still running to purge all water standing above the bottom intake.
12) Dispose of the tubing after use, unless it is dedicated.
13) Monitor indicator parameters as discussed previously.

Sampling Instructions:

- A centrifugal pump is not suitable and may not be used for sample collection.

G. Peristaltic Suction Pump

A peristaltic pump can be used to purge shallow, small diameter wells at a low to modest rate. The lift capacity is very limited with these pumps and often exceeded at groundwater depths of greater than 20 to 25 feet (depending upon pump size). This type of pump is normally used with dedicated tubing. Peristaltic pumps can also be used for sample collection for parameters that are not pH or pressure sensitive. Collecting groundwater samples from these pumps is only appropriate if approved project-specific planning documents specifically include this technique for collecting samples.

Required Equipment:

- Peristaltic pump, electric powered 12 VDC.
- 12 VDC power source, such as a sealed motorcycle battery or connection to vehicle battery.
- 3/8" to 1/2" PE, PP, or Teflon® tubing of appropriate length.
- 5/8" OD, 3/8" ID medical grade silicone tubing. Do not attempt to use Tygon® tubing.
- New disposable gloves of appropriate material.
- New PE sheeting.
- Five gallon pail, graduated in minimum one gallon increments.
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.
2) Don a new pair of gloves.
3) Replace the silicone tubing in the pump head if the pump will used for sample collection.
4) Lower the tubing into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting.
5) Place the intake of the tubing as high in the well as possible but deep enough that it will not break suction.

Purging Instructions:

1) Connect the tubing to the pump.
2) Determine the volume of water to be purged, as described above.
3) Start the pump.

4) Direct the pump discharge to the five gallon pail and determine the pumping rate.
5) Continue pumping until the necessary volume of water has been purged from the well.
6) If the pump intake tubing has been placed deeply down into the water column for some reason, slowly withdraw the tubing upward through the water column while it is still running to purge all water standing above the bottom intake.
7) Dispose of the tubing after use.
8) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.
2) Resume pumping and adjust to a slow pumping rate, (approximately 100 ml/min) if the pump is equipped with a speed control.
3) Collect the samples by pumping directly into each of the required containers.
4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).
5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge.

H. Inertial Lift Pump

An inertial lift pump is a very simple device that can be used to purge and sample wells of almost any diameter to a depth of approximately 100 feet. This type of pump is normally dedicated to the well. Collecting groundwater samples from these pumps is only appropriate if approved project-specific planning documents specifically include this technique for collecting samples.

Required Equipment:

- 1/2" OD HDPE pump tubing
- Check valve
- Electric motor driven lift arm [OPTIONAL]
- Electric power source [OPTIONAL]
- New disposable gloves of appropriate material
- New plastic sheeting
- Five gallon pail, graduated in minimum one gallon increments
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

1) Place new polyethylene (PE) sheet on suitable surface adjacent to well, taking care not to step on the PE sheet.

2) Don a new pair of gloves.

3) Decontaminate equipment and pump (if not dedicated).

4) Install self threading valve on the bottom of the tubing

5) Lower pump slowly into the well, being careful not to contact any surface other than the interior of the well or the plastic sheeting. When lowering the pump be particularly sensitive to areas that suggest drag or problems in the well where the pump could get stuck. If a problem exists do not continue, but discuss ways to investigate with PM or senior technical personnel.

6) Place the tubing intake as high in the well as is possible but deep enough that it will not break suction. The tubing intake can be placed deeper in the well if the inertial lift pump will also be used for sample collection.

Purging Instructions:

1) Refuel the electric generator, if used, at a location that is remote from the well, being very careful not to spill any fuel on equipment or clothing that will be used at the well site.

2) Place the generator as far from the well as possible in a down-wind direction.

3) Don a new pair of gloves after handling the generator.

4) Connect the tubing to the pump arm, if used.

5) Determine the volume of water to be purged, as described above.

6) Start pumping by working the pump tubing in an up and down motion.

7) Direct the pump discharge to the five gallon pail and determine the pumping rate.

8) Continue pumping until the necessary volume of water has been purged from the well.

9) If the pump intake tubing has been placed deeply down into the water column for some reason, slowly withdraw the tubing upward through the water column while it is still running to purge all water standing above the bottom intake. This should be accomplished by reconnecting the pump arm at progressively lower points on the tubing and allowing the pump to operate for short periods of time. This step is not required if the inertial lift pump will be used for sample collection.

10) Dispose of the tubing after use, unless it is left in the well.

11) Monitor indicator parameters as discussed previously.

Sampling Instructions:

1) Allow the well to recharge after completion of purging, if necessary.

2) Resume pumping at a slow rate either by decreasing the speed of the lift arm unit or by operating the tubing manually.

3) Collect the samples by pumping directly into each of the required containers.

4) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

5) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the pump discharge.

I. Domestic Water Supply System

Sampling a domestic well requires minimal equipment since the domestic water supply system includes a pump and pressurization tank that delivers a reliable sample stream under pressure.

Required Equipment:

- Five gallon bucket, graduated in minimum one gallon increments
- Water quality monitoring equipment (preferably a flow through cell).

Installation Instructions:

- None required.

Purging Instructions:

1) Following notification of the landowner (refer to Section 5.2.3), arrive at the location and immediately knock on the front door to see if anyone is home and to announce your presence. There is no reason to enter the home.
2) Don a new pair of gloves.
3) Go to the outside spigot closest to the well.
4) Remove the hose from the spigot. If necessary, the hose may be left on the spigot for purging, but it must be removed prior to sampling.
5) Turn on the spigot.
6) Measure and record the approximate purge flow rate (gpm) by conducting a bucket test.
7) Allow at least 20 gallons to flow through the spigot. Collect the water in the bucket and pour the purge water on the landscaping.
8) Monitor indicator parameters consisting of pH, specific conductivity, and temperature. The domestic water supply system is considered stabilized when three consecutive readings vary by less than 10% or pH changes by less than 0.1 pH units.

Sampling Instructions:

1) When at least 20 gallons have been purged and pH, specific conductivity, and temperature have stabilized, the domestic water supply system is ready to be sampled.

2) Collect the samples by filling the required containers directly from the spigot. The valve on the spigot should be turned almost to the closed position to provide a low sampling flow rate that is as laminar as possible.

3) Bottles should be filled in order of sensitivity to volatilization and oxidation as discussed in Section 5.1.3 or as outlined in project-specific planning documents. Care should be taken to ensure that no head space remains in the volatile organic vials. Certain other parameters may also require minimizing headspace (e.g., reduced or ferrous iron).

4) Filtered samples can easily be obtained by installing an in-line, 0.45 µm disposable cartridge filter directly onto the spigot.

5) Turn off spigot and re-attach hose.

5.2.7 Field Measurements

The final determination of pH, specific conductance, and temperature should be made immediately upon collection of the samples. It is preferred that these parameters be measured continuously using a water quality meter coupled with a "flow through" cell. Alternately, these measurements would be made in an aliquot contained in a disposable plastic cup.

5.3 FIELD RECORDS

Accurate field records must be maintained to document groundwater sampling activities. These records include technical field data, sample identification labels, and chain-of-custody information for each sample.

Specifically for groundwater sampling, the field sampling records should include, at a minimum, the following information:

- Sampling location
- Date and time
- Condition of the well
- Static water level (depth to water)
- Calculated well volume
- Purging method
- Actual purged volume
- Sample collection method
- Sample description
- Field meter calibration data
- Water quality measurements
- General comments (weather conditions, etc.)

All data entries should be made using black indelible ink and should be written legibly. Entry errors should be crossed out with a single line, dated, and initialed by the person making the correction. An example of a form that could be used to record field sampling data is shown in Attachment D.

5.4 SAMPLE SHIPMENT

Shipment of samples to an analytical laboratory is usually required upon completion of sample collection. Proper packaging is necessary in order to protect the sample containers, to maintain the samples at or below a temperature of 4°C, and to comply with all applicable transportation regulations.

5.5 SPECIAL REGULATORY REQUIREMENTS

A number of states and USEPA regions have specific groundwater sampling requirements that must be followed. These requirements must be determined in advance, and should be incorporated in to the project specific planning documents.

6.0 QUALITY ASSURANCE/QUALITY CONTROL

In order to assess the accuracy and precision of the field methods and laboratory analytical procedures, quality assurance/quality control (QA/QC) samples are collected during the sampling program according to the project Work Plan. QA/QC samples may be labeled with QA/QC identification numbers or fictitious identification numbers if blind submittal is desired, and are sent to the laboratory with the other samples for analyses. The frequency, types, and locations of QA/QC samples are specified in the project QAPP or Work Plan. Examples of QA samples include, but are not limited to, equipment rinsate blanks, field blanks, trip blanks, duplicate samples, and matrix spike/matrix spike duplicate samples.

6.1 Equipment Rinsate Blanks

An equipment rinsate blank is intended to check if decontamination procedures have been effective and to assess potential contamination resulting from containers, preservatives, sample handling and laboratory analysis. Procedures for collection are as follows:

1. Rinse the decontaminated sampling apparatus with deionized water. Allow the rinsate to drain from the sampling apparatus directly into the sample bottle or into a secondary container which is then poured into the sample bottle;
2. Add any preservatives associated with the sample analytical methods to the rinsate sample;
3. Specify (on the COC) the same analytical methods for rinsate samples as is specified for the groundwater samples;
4. Assign the rinsate sample an identification number and label as rinsate samples; and
5. Place the rinsate sample in a chilled cooler and ship it to the laboratory with the other samples.

A field blank sample will be collected for every 20 samples (or less) each day samples are collected.

6.2 Field Blanks

Analyses of field blanks are used to assess the contamination of samples during sample collection. Field blanks are prepared at a sampling location by pouring certified analyte-free water provided by the laboratory into a preserved container. The field blank sample should be analyzed by the same methods as the groundwater sample. An identification number shall be assigned and recorded in the log book which groundwater sample location the field blank was prepared at. A field blank will be collected and analyzed for every 20 investigative samples that are collected.

6.3 Trip Blanks

Trip blanks are volatile organic samples that are prepared in the laboratory using analyte-free water. Trip blanks are analyzed to assess VOC contamination of samples during transport and are used only when VOCs are suspected and being analyzed in the groundwater samples. One trip blank (three 40 ml vials) will be included for each cooler that contains samples for VOC analysis. At no time should the trip blanks be opened by field personnel.

6.4 Duplicate Samples

Duplicate samples are collected to assess the precision of field and laboratory components of field samples. When collecting a duplicate groundwater sample, the original and duplicate sample containers should be filled simultaneously, or as close to simultaneous as possible, by moving the discharge tubing or bailer back and forth over each container until they are full. Alternatively, the sample could be collected in one larger container, mixed, and split into the original and duplicate samples. This method will give a more representative split but also is more likely to introduce contamination if the larger container is reused and is therefore not preferred.

To maximize the information available in assessing total precision, collect duplicate samples from locations suspected of the highest contaminant concentration. Use field measurements, visual observations, past sampling results, and historical information to select appropriate locations for duplicate analyses.

The duplicate sample is handled and preserved in the same manner as the primary sample and assigned a sample number, stored in a chilled cooler, and shipped to the laboratory with the other samples. Whenever possible, the sample identification numbers for the characteristic sample and its duplicate are independent such that the receiving laboratory is not able to distinguish which samples are duplicates prior to analysis.

One duplicate sample shall be collected per 20 (or less) investigation samples.

6.5 Matrix Spike/Matrix Spike Duplicate Samples

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. Following shipment of the samples to the laboratory, the laboratory prepares MS and MSD samples by splitting the material into three separate sets of containers and spiking the split samples with appropriate analytes prior to performing the extraction in order to evaluate the total of the spiked compound and whatever quantity of the compound may be present in the sample. Results of the analyses are compared with the results of the primary sample and the known concentrations of the spike compounds. The percent recovery and relative percent difference are calculated and results are used to evaluate the precision and accuracy of the analytical method for various labeled "extra volume samples for MS/MSD." The sample volumes required for these analyses should be coordinated with the laboratory and are described in the project Work Plan.

At least one set of MS/MSD samples will be analyzed per 20 (or less) samples received.

7.0 REFERENCES

American Society for Testing Materials. "D 4448, Standard Guide for Sampling Groundwater Monitoring Wells."

Armstrong, R. and F.R. McLaren, 1984. "The Suction Side Sample Catcher in Ground Water Quality Sampling," Ground Water Monitoring Review, Fall 1984, pp. 48-53.

Barcelona, M.J., J.P. Gibb, J.A. Helfrich and E.E. Garske, 1985. Practical Guide to Groundwater Sampling, Illinois State Geological Survey Contract Report 374, pp. 94.

Barcelona, M.J., and J.A. Helfrich, 1986. "Well Construction and Purging Effects on Ground-Water Samples," Environmental Science and Technology, vol. 20, no. 11, pp. 1179-1184.

Barcelona, M.J., J.A. Helfrich, and E.E. Garske, 1988. "Verification of Sampling Methods and Selection of Materials for Ground-Water Contamination Studies," Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, pp. 221-231.

Barker, J.F. and R. Dickhout, 1988. "An Evaluation of Some Systems for Sampling Gas-Charged Ground Water for Volatile Organic Analysis," Ground Water Monitoring Review, Fall 1988, v. 8, no. 4, pp. 112-120.

Claassen, H.C., 1982. Guidelines and Techniques for Obtaining Water Samples That Accurately Represent the Water Chemistry of an Aquifer, U.S. Geological Survey, Open-File Report 82-1024, Lake, Colorado, pp. 49.

Clarke A.N., D. R. Davis and J. H. Clarke, “Environmental Project Definition with the Analytical Laboratory: The First Step Toward Total Quality Assurance,” American Environmental Laboratory, October, 1990.

Ficken, J.H, 1988. "Recent Development of Downhole Water Samplers for Trace Organics," Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, pp. 253-257.

Gibb, J.P., R.M. Schuller and R.A. Griffin, 1981. Procedures for the Collection of Representative Water Quality Data from Monitoring Wells. Illinois State Water Survey Cooperative Groundwater Report 7.

Gibb, J.P., R.M. Schuller, and R.A. Griffin, 1980. Monitoring Well Sampling and Preservation Techniques, EPA-600/9-80-101.

Gibs, Jacob, and Thomas E. Imbrigiotta, 1990. "Well-Purging Criteria for Sampling Purgeable Organic Compounds," Ground Water, vol. 28, no. 1.

Giddings, T., 1983. "Bore-Volume Purging to Improve Monitoring Well Performance: An Often-Mandated Myth," Proceedings of the Third National Symposium on Aquifer Restoration and Ground Water Monitoring, National Water Well Association, Dublin, Ohio, pp. 253-256.

Gillham, R.W., M.J.L. Robin, J.F. Barker and J.A. Cherry, 1983. Groundwater Monitoring and Sample Bias, Environmental Affairs Department, American Petroleum Institute, pp. 206.

Herzog, B.L., S.J. Chou, J.R. Valkenburg, and R.A. Griffin, 1988. "Changes in Volatile Organic Chemical Concentrations After Purging Slowly Recovering Wells," Ground Water Monitoring Review, Fall 1988, v. 8, no. 4, pp. 93-99.

Herzog, B., J. Pennino, and G. Nielsen, 1991. "Ground-Water Sampling," Practical Handbook of Ground-Water Monitoring, David M. Nielsen editor, Lewis Publishers, Chelsea, MI, pp. 449-499.

Ho, J.S.Y., 1983. "Effect of Sampling Variables on Recovery of Volatile Organics in Water," Journal of American Water Works, November 1983, pp. 583-586.

Imbrigiotta, T.E., J. Gibs, T.V. Fusillo, G.R. Kish, and J.J. Hochreiter, 1988. "Field Evaluation of Seven Sampling Devices for Purgeable Organic Compounds in Ground Water," Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, pp. 258-273.

Kasper, R.B. and J.A. Serkowski, 1988. "Evaluation of Sampling Equipment for RCRA Monitoring in a Deep Unconfined Aquifer," Proceedings of the Second National Outdoor Action Conference on Aquifer Restoration and Ground Water Monitoring, National Water Well Association, Worthington, Ohio, pp. 445-455.

McAlary, T.A. and J.F. Barker, 1987. "Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials," Ground Water Monitoring Review, Fall 1987, pp. 63-68.

NCASI, 1982. "A Guide to Groundwater Sampling", NCASI Technical Bulletin, No. 362, January 1982.

New Jersey Department of Environmental Protection, 1988. Field Sampling Procedures Manual, pp. 414

Nielsen, D.M. and G.L. Yeates, 1985. "A Comparison of Sampling Mechanisms Available for Small-Diameter Ground Water Monitoring Wells," Ground Water Monitoring Review, Spring 1985, pp. 83-99.

Panko, A.W. and P. Barth, 1988. "Chemical Stability Prior to Ground-Water Sampling: A Review of Current Well Purging Methods," Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, pp. 232-239.

Rannie, E.H. and R.L. Nadon, 1988. "An Inexpensive, Multi-Use, Dedicated Pump for Ground Water Monitoring Wells," Ground Water Monitoring Review, Fall 1988, v. 8, no. 4, pp. 100-107.

Scalf, M.R., J.F. McNabb, W.J. Dunlap, R.L. Cosby, and J.S. Fryberger, 1981. Manual of Ground-Water Quality Sampling Procedures, September 1981, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, EPA-600/2-81-160.

Schalla, R., D.A. Myers, M.A. Simmons, J.M. Thomas, and A.P. Toste, 1988. "The Sensitivity of Four Monitoring Well Sampling Systems to Low Concentrations of Three Volatile Organics," Ground Water Monitoring Review, Summer 1988, pp. 90-96.

Schuller, R.M., J.P. Gibb, and R.A. Griffin, 1981. "Recommended Sampling Procedures for Monitoring Wells," Ground Water Monitoring Review, Spring 1981, pp. 42-46.

United States Environmental Protection Agency Region IV, 1996. Environmental Investigations and Standard Operating Procedures and Quality Assurance Manual, 1996, pp. 7-1 - 7-10.

United States Environmental Protection Agency, 1991. Compendium of ERT Groundwater Sampling Procedures, EPA/540/P-91/007, January 1991.

Unwin, J.P. and D. Huis, 1983. "A Laboratory Investigation of the Purging Behavior of Small-Diameter Monitoring Well," Proceedings of the Third Annual Symposium on Ground Water Monitoring and Aquifer Restoration, National Water Well Association, Dublin, Ohio, pp. 257-262.

Unwin, J. and V. Maltby, 1988. "Investigations of Techniques for Purging Ground-Water Monitoring Wells and Sampling Ground Water for Volatile Organic Compounds," Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, pp. 240-252.

8.0 ATTACHMENTS

Attachment A - Groundwater Sampling Checklist

Attachment B - Summary of Well Sampling Equipment

Attachment C - Purging and Sampling Equipment Matrix

Attachment D – Example Groundwater Sampling Field Data Sheet

ATTACHMENTS

Attachment A. Groundwater Sampling Checklist

Planning

- ☐ Select well purging method
- ☐ Determine well purging strategy
    - ☐ Purging until of indicator parameters stabilize (±10%).
    - ☐ Purge predetermined number of well volumes (usually 3 to 5).
    - ☐ Low yield wells purged until dryness.
    - ☐ Others
- ☐ Determine containerization and disposal method for purge water
- ☐ Select well sampling method
- ☐ Determine groundwater sampling sequence

Preparatory Office Activities

- ☐ Obtain and decontaminate appropriate purging and sample collection equipment.
- ☐ Obtain appropriate sample containers and preservatives from laboratory.
- ☐ Inventory sample containers and preservatives.
- ☐ Pre-label sample containers.
- ☐ Initiate field data record for each well.
- ☐ Communicate sampling schedule with analytical laboratory and site contact or other parties, as required.

Preparatory Field Activities

- ☐ Perform well maintenance check.
- ☐ Prepare clean work area.
- ☐ Determine the depth to groundwater (±0.02 ft).
- ☐ Calculate the water volume standing in the well (±2%).

Well Purging

- ☐ Place purging device at proper depth to ensure complete purging of well (if device is not also used for sample collection).
- ☐ Purge well, following previously selected strategy.
- ☐ Handle and dispose of purge water using previously determined method.

Well Sampling

- ☐ Collect groundwater sample.
- ☐ Fill containers and made field determinations in order of decreasing sensitivity to volatilization and/or pH change.
- ☐ Fill all other sample containers.
- ☐ Record all technical data.
- ☐ Maintain chain of custody records.
- ☐ Pack and ship samples to prevent breakage, to maintain sample temperature of 4°C and to comply with Dangerous Goods regulations.

Attachment B. Summary of Well Sampling Equipment

Description	Well Diam. (inches)	Depth Limit (feet)	Can it be Dedicated?	Materials	Reduce Flow to 100ml/m?	Acceptable for: VOC	Acceptable for: pH Sensitive	Advantages	Disadvantages	Manufacturers
Bailer										
Tube with bottom and/or top check valve, suspended by line.	Unlimited	Unlimited	Yes	• PVC • Teflon ® • HDPE • SS	Yes	Yes	Yes	• Simple, inexpensive • Can yield high quality samples if used carefully • No power required • Easily cleaned	• Awkward to use • Can aerate sample if not used carefully • Increases chance of turbid samples • Flow not continuous	Timco: Johnson: Voss:
Small Diameter (2") Electric Submersible Pump										
Electrically driven impeller pump.	2 - 4	400	Yes	• SS / Teflon ®	Yes	Yes	Yes	• Easy to operate • Easy to control • Continuous flow	• High capital cost • Awkward if not dedicated	Grundfos
Large Diameter (4") Electric Submersible Pump										
Electrically driven impeller pump.	>=4	unlimited	Not typically	• SS	No	No	No	• Continuous flow	• May not be compatible with VOC & pressure sensitive parameters	Grundfos
Peristaltic (Suction) Pump										
Elastic tubing that is sequentially squeezed by rollers.	<=2	± 25	Yes, internal elastic tubing & pump tubing	• Teflon ® • HDPE • PP	No	Yes		• Flow rate easily controlled, continuous • Portable • Inexpensive • No pump contact with sample	• Loss of VOC due to reduced pressure • Requires power source • May require priming • Can impede access	Isco, Masterflex

<u>Notes</u>:

SS: Stainless Steel
HDPE: High density polyethylene
VAC: Voltage AC Source
PVC: Polyvinyl Chloride
VOCs: Volatile Organic Compounds
PP: Polyprplene

Attachment C - Purging and Sampling Equipment Matrix

Methods	4 inch wells									2 inch wells									<2 inch wells								
	Water Level < 20'						W.L. > 20'			Water Level < 20'						W.L. > 20'			Water Level < 20'						W.L. > 20'		
	Cs>0.2			Cs<0.2						Cs>0.2			Cs<0.2						Cs>0.2			Cs<0.2					
		Sample			Sample			Sample			Sample			Sample			Sample			Sample			Sample			Sample	
	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other	Purging	VOC/pH	Other
Methods Described in this SOP																											
Bailer	X	X	X	X	X	X	I	X	X	X	X	X	X	X	X	I	X	X	X	X	X	X	X	X	X	X	X
2" Electric Submersible Pump	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
4" Electric Submersible Pump	X	O	X	X	O	X	X	O	X																		
Peristaltic Pump	X	O	X							X	O	X							X	O	X						
Other Methods To Consider																											
Bladder Pump	X	X	X	X	X	X	I	X	X	X	X	X	X	X	X	X	X	X									
Gas Driven Piston Pump	X	X	X	X	X	X	I	X	X	X	X	X	X	X	X	X	X	X									
Centrifugal Pump	X									X									X								
Syringe Sampler		X	X		X	X		X	X		X	X		X	X		X	X									
Inertial Lift Pump	X	O	X	X	O	X	I	O	X	X	O	X	X	O	X	X	O	X	X	O	X	X	O	X	X	O	X

Notes: W.L. - Water Level
Cs - Specific Capacity (gallons per foot of drawdown)
VOC - Volatile Organic Compounds
X - Recommended method.
O - Conditionally acceptable Method, based upon technical concerns.
I - Inefficient method but technically acceptable.
- Not recommended or not feasible.

GROUNDWATER PURGE AND SAMPLING FIELD DATA SHEET

1. PROJECT INFORMATION

WELL ID: ______

Project Number:_____________ Task Number:_________ Date:____________________ Time:____________

Client:____ Personnel:____

Project Location:___________________________________ Weather:____

2. WELL DATA

Casing Diameter:__________ inches | Type of Casing: ___________________________

Screen Diameter:__________ inches (d) | Type of Screen:__________________________ Screen Length : ________________

Total Depth of Well from TOC:______________ feet

Depth to Static Water from TOC:_____________ feet

Depth to Product from TOC:_________________ feet

Length of Water Column (h):_____________ feet Calculated Casing Volume:___________ gal (3 to 5 times one well volume)

Purge Volume Calculation (one casing volume = $0.041d^2h$):

Note: 2-inch well = 0.167 gal/ft 4-inch well = 0.667 gal/ft

3. PURGE DATA

Purge Method: ______________________________

Materials: Pump/Bailer ______________________________

Materials: Rope/Tubing ______________________________

Was well purged dry? ❑ Yes ❑ No Pumping Rate: gal/min

Equipment Model(s)

1. _______________________

2. _______________________

Time	Cum. Gallons Removed	pH	Temp (Units)	Spec. Cond. (Units)	Eh (Units)	DO (Units)	Turbidity (NTU)	Other: ___________	Comments	

4. SAMPLING DATA

Method(s): ______________________________

Materials: Pump/Bailer ______________________________

Materials: Tubing/Rope ______________________________

Depth to Water at Time of Sampling:____________ Field Filtered? ❑ Yes ❑ No

Sample ID:_____________ Sample Time:_____________ # of Containers:_______

Duplicate Sample Collected? ❑ Yes ❑ No ID:_____________

Analyses Requested:

5. COMMENTS

____