ATTACHMENT 8 – QUALITY ASSURANCE
Groundwater Monitoring Wells Installation Project – Sylmar Basin
Los Angeles Department of Water and Power

Quality Assurance and Quality Control (QA/QC) measures that will be used during the Project are discussed generally in the Workplan (Attachment 5) and included in Specification 7315.

"Part F, Detailed Specifications, Division F2 – Site Construction, Section F02523 – Monitoring Wells in the Sylmar Basin" of the Specification (attached) provides well construction requirements to ensure that the wells are properly constructed and provide groundwater samples that will be representative of aquifer conditions.

- Part 1, Section 1.04 provides references for standards and specifications.
- Section 1.05 provides a list of submittals to be submitted by the Selected Contractor including the following:
  - Qualifications of the geophysical borehole logging subcontractor;
  - Mix designs for cement grout, annular seals and sanitary seals;
  - Manufacturer certification and documentation for well materials; and
  - Well Development Work Plan.
- Section 1.08 provides general requirements to which the work must conform.
- Part 2 provides product specifications that must be met by the Selected Contractor.
- Part 3 provides execution requirements that the must be met by the Selected Contractor.

Additional technical submittals and various plans are also required per the Specification and Workplan and will be prepared before the commencement of construction, including the following:

- Site-specific health and safety plans;
- Traffic Control Plans;
- Wet Weather Erosion Plan;
- Well Development Work Plan;
- Drilling Mud Management Plan; and
- Site Plan and Waste Management Work Plan.

As discussed in the Workplan, a LADWP Project Manager from the Water Engineering Technical Services Division will oversee the work of the Selected Contractor and the Consulting Project Geologist in consultation with a Project Engineer from the Water Quality Division to ensure that the terms of the Specification and Contract are met.

LADWP staff will work with the Consulting Professional Geologist to develop a Sampling and Analysis Plan (SAP) for the project. At a minimum, the SAP will address soil and groundwater sampling procedures; sample documentation, storage, handling and shipment; quality assurance procedures; and laboratory methods for the selected analytes. An example of a SAP prepared for a previous LADWP well installation project with the Army Corps of Engineers is also attached. The SAP for this Project is expected to be similar.

Samples will be analyzed by the LADWP Water Quality Laboratory, LADWP Environmental Laboratory or other California-certified laboratory under contract with LADWP.

PART F - DETAILED SPECIFICATIONS
DIVISION F2 – SITE CONSTRUCTION

SECTION F02523 – MONITORING WELLS IN SYLMAR BASIN

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. For an understanding of the complete contract, reference is made to a statement of the Contract Documents in Division D1.

1.02 SUMMARY

A. Optional work to construct up to 5 groundwater monitoring wells in the Sylmar Basin, which is located in Los Angeles County, California.

1.03 RELATED SECTIONS

A. Section F01330 – Submittals.

B. Section F01322 – Record Documents.

C. Section F01780 – Operation and Maintenance Manuals.

1.04 REFERENCES

A. American National Standards Institute/American Water Works Association (ANSI/AWWA) A100-06.

B. California Department of Water Resources Southern District (CDWR) California Well Standards Bulletins 74-81 and 74-90.

C. American Society for Testing and Materials (ASTM) Annual Book of ASTM Standards.

D. Standard Specifications for Public Works Construction (SSPWC) and the additions and supplements of the City of Los Angeles (“Brown Book”).

E. United States Environmental Protection Agency (USEPA) Groundwater Issue Paper #EPA 542-S-02-001 “Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers”, (Yeskis and Zavala, May 2002).

F. USEPA Groundwater Issue Paper #EPA 540-S-95-504 “Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures”, (Puls and Barcelona, April 1996).

G. American Welding Society (AWS) “Welding Handbook”.

H. American Petroleum Institute (API), Spec 10A.

I. Guidance Document for the NPDES Discharge Permit, Number CAG994005, CI-9255 for the Mission Wellfield Groundwater Study Project.

J. Guidance Document for the Industrial Waste Discharge Permit Number W-496163 for Mission Wellfield Sanitary Sewer as used by the Mission Wellfield Groundwater Study Project.

K. Guidance Document for the Industrial Waste Discharge Permit Number W-208712 for Van Nuys Service Center as used by the Groundwater System Improvement Study (GSIS).

L. American National Standards Institute/American Petroleum Institute (ANSI/API) RP 13B-1: Recommended Practice for Field Testing Water-Based Drilling Fluid.

1.05 SUBMITTALS

A. Submit the following in accordance with Section F01330:

1. Completed and signed “Los Angeles Department of Water and Power Wet Weather Erosion and Sediment Control Plan” template for each drill site.

2. Drilling Mud Management Plan for each drill site: Designed by a qualified mud engineer and stamped by a registered professional geologist. Include proposed equipment and layout, conveyance piping, power supply, materials, and additives proposed for use in the drill mud, and procedures for managing drill mud properties.

3. Site Plan and Waste Management Work Plan for each drill site. Include layout of drill rig, support rig, equipment, waste storage containers, roll-off bins, and tanks. Include disposal sites, operating hours for transportation of waste materials, and anticipated maximum truck trips per day. Describe method for facilitating public access, refuse collection from neighboring properties, and other property access needs.

4. Certifications and Material Safety Data Sheets (MSDS) of all proposed drilling mud additives.

5. Company name and qualifications of the geophysical borehole logging subcontractor demonstrating the following experience:

- **a.** Not less than 5 years conducting the required suite of geophysical logging on boreholes similar in scope to this contract.
- **b.** Conducting and interpreting geophysical logging for public agencies or for groundwater investigations in the groundwater basins of the Los Angeles area.
- **c.** Calibrating geophysical logging tools.

6. Mix design of cement grout to be installed in the annular space exterior to the conductor casing.

7. Mix design of the annular seal and sanitary seal to be installed in the annular space exterior to the PVC well casings.

8. Certificate of sand filter pack material quality and gradation, including sieve analysis of representative samples from each batch delivered to each site.

9. Manufacturer’s certification of conductor casing materials conforming to ASTM A139 or ASTM A53.

10. Manufacturer’s documentation of PVC well casing materials certifying conformance to ASTM D1785 and ASTM F480 and documenting the source of resin materials used in the manufacture of PVC well casing materials supplied for this contract.

11. Material list and working drawings of the well casing assembly and incorporated components of the Zone Isolation Sampling Technology (ZIST™) system approved by the manufacturer. Certify compatibility of the well casing sections with the ZIST™ on the working drawings by signature of the Contractor and the authorized representative of BESST, Inc.

12. Surface completion material list and working drawings. Include installation details for EMCO Wheaton Retail A0721-218 Manhole, EMCO Wheaton Retail A0717-124B Manhole, locking covers, and watertight locking well casing caps. Clearly show transducer data cables and ZIST™ tubing are accessible within the vault enclosure.

13. Well Development Work Plan for each drill site. Include all well development processes, methods, equipment and layout, tools, holding tank(s), conveyance piping, and MSDS of dispersants.

14. Manifests for solid and liquid waste disposal to permitted waste disposal facilities approved by the Engineer for the project. Obtain the Engineer's signature on manifests prior to transporting wastes from each site. Arrange for one original of each waste manifest to be signed and mailed to the Engineer by the waste disposal facility operator certifying receipt of wastes for disposal.

15. As-constructed drawings of each completed well as specified in Subarticle 3.05J of this Section.

16. Wastewater Treatment Work Plan (required only if Option Item 113 is exercised). Include all components and layout of the temporary granular activated carbon wastewater treatment system and operating procedures.

B. Submit Operation and Maintenance Manuals as defined in Section F01780 for all instruments.

1. Provide a summary of all settings of each instrument and procedures for unit re-calibration.

2. O&M manuals for ZIST™ systems shall include a record of all cycle times for operating the ZIST™ Multi-Zone Timer Controller in Purging Mode and Sampling Mode recommended for the operation of each ZIST™ pump as installed in each completed well.

1.06 MANUFACTURER'S WARRANTIES

A. Provide the following manufacturer's warranties, which shall commence on Final Acceptance:

1. ZIST™ System: 5 years.

2. In-Situ Products, including Level Troll 500, Rugged Cable System: 5 years.

1.07 NOT USED

1.08 GENERAL REQUIREMENTS

A. All work shall conform to the following requirements:

1. American National Standards Institute/American Water Works Association (ANSI/AWWA) A100-06.

2. California Department of Water Resources Southern District (CDWR) California Well Standards Bulletins 74-81 and 74-90.

3. Well drilling permit requirements of the Los Angeles County Department of Public Health.

1.09 ADDITIONAL SERVICES

A. The Engineer reserves the right to issue Change Orders directing the Contractor to provide any of the following additional services:

1. Well removal, abandonment, and destruction:

a. Clean the well to remove undesirable materials and obstructions. Remove conductor casing and annular seal to a depth not less than 20 feet below ground surface.

b. Place low permeability sealing material, such as sand cement or Bentonite grout. Place materials under pressure using a tremie pipe to prevent freefall, bridging, and dilution of sealing material through the borehole. Place materials continuously throughout the interval being filled to within 5 feet below ground surface. Backfill the final 5 feet with cement slurry.

c. Furnish a record of all well destruction procedures in accordance with Section F01322.

d. Change Orders will not be issued for terminating and destroying borehole(s) if such termination is due to Contractor negligence.

2. Well maintenance, including removal and replacement of instrumentation.

3. Well Redevelopment: Remobilize and perform additional well development beyond the work required in Article 3.07 of this Section.

4. Video survey.

PART 2 – PRODUCTS

2.01 CONDUCTOR CASING

A. Manufactured in accordance with ASTM A 139 Grade B or ASTM A 53 Grade B.

B. Welding shall be by the automatic submerged-arc process using not less than one pass on the interior surface and not less than one pass on the exterior surface.

C. Inside diameter as directed by the Engineer, lengths of not less than 10 feet, and wall thickness of not less than 0.25 inch.

D. The ends of each joint shall be machine beveled perpendicular to the casing axis to ensure the straightness of each assembled section. One end of each assembled section shall be fitted with a 6-inch wide collar welded to the pipe so that the collar will be equally spaced on either side of the joint. Provide 3 equally spaced alignment holes in each collar.

2.02 WELL CASINGS

A. General Requirements:

1. Manufactured in accordance with ASTM D 1785 and ASTM F 480.

2. Schedule 80 Polyvinyl Chloride (PVC) in lengths of not less than 10 feet.

3. One-inch, 2-inch, and 4-inch diameter blank section well casings in total lengths required for installation to one or more zones below ground surface as directed by the Engineer.

4. Flush threaded symmetrical with the well casing wall thickness.

5. O-ring seals: Viton material, sized to seat properly within the o-ring groove of the flush threaded connection without the need for over-stretching the o-ring.

6. Compatible with the components of the ZIST™ system which shall be incorporated into the completed assembly of the well casing.

B. PVC Slotted Well Screens:

1. Schedule 80 Polyvinyl Chloride (PVC).

2. The slotted well screens shall be 0.020 inches milled slots, or as otherwise directed by the Engineer, based on the results of the Contractor's sieve analysis of representative formation samples from the pilot borehole.

3. One-inch, 2-inch, and 4-inch slotted well screens in total lengths of 40 feet as directed by the Engineer for installation in each of one or more zones.

4. Install 10 feet of blank well casing below each interval of slotted well screens, fitted with a closed shoe or plug.

2.03 SAND FILTER PACK

A. "6 x 12 Colorado Silica" Oglebay Norton Industrial Sand filter pack material, or alternate gradation as directed by the Engineer based on results of the Contractor's sieve analysis of formation samples collected from the pilot borehole.

B. Hard, well-rounded siliceous rock or water-worn sand and gravel. Wash clean of dirt, silt, clay, organic material, and other foreign substances. Do not furnish crushed rock or pea gravel.

C. Contain not less than 80 percent silica content and not more than 5 percent calcareous materials.

D. Specific Gravity: 2.5 or greater.

E. Keep free of debris and all foreign matter at all times.

2.04 TRANSITION SEAL

A. Seal above sand filter pack material shall consist of 100 percent Baroid bentonite clay pellets or chips.

2.05 ANNULAR SEAL AND SANITARY SEAL

A. Annular Seal for Steel Conductor Casing:

1. Used to seal the exterior annular space.

2. ASTM C 150 Type II (API Class B) cement.

3. Mix Design: Sand-cement grout equivalent to a 10.3-sack mix.

4. If used, additives mixed with the sealing material to accelerate the curing time or to expand the material shall not exceed the following:

a. 2 percent calcium chloride.

b. 4 percent bentonite.

B. Annular Seal for PVC Well Casings:

1. Used to seal the exterior annular space below the surface sanitary seal.

2. Mix Design: Equal parts Baroid Bentonite granular clay and sand, dry mixed prior to placement.

3. Sand material: Medium grain size passing the U.S. Standard Sieve mesh #35 and retained in the U.S. Standard Sieve mesh #60, and consist of rounded, non-reactive material. Do not furnish crushed aggregate.

4. Do not add additives to accelerate the cure time.

C. Sanitary Surface Seal:

1. Used to seal the exterior annular space of the PVC well casings below the final ground surface.

2. Mix Design: ASTM C150 Type II (API Class B) cement with up to 6 percent Baroid bentonite clay.

3. Do not use additives to accelerate the cure time.

2.06 INSTRUMENTATION

A. ZIST™ - Option Items 100 through 105:

1. Manufacturer: BESST, Inc.

2. Provide all components necessary for the intended use of collecting groundwater samples under low-flow and minimal drawdown conditions, including ZIST™ Docking Receivers, Blatypus Pumps, Blatymini Pumps, ZIST™ Docking Weights with Viton o-rings, Perforated Drop-Tube Extensions, volume displacement stems, system pressurization and sample-return 3/8-inch x 1/4-inch tubings, ZIST™ Centralizers, well-head assemblies, and programming schedule for ZIST™ Multi-Zone Timer Control Unit.

3. Modify system configuration and components to suit the site-specific requirements and conditions for each monitoring well at the direction of the Engineer.

B. In-Situ Level Troll 500 (Non-Vented) – Option Item 106:

1. Manufacturer: In-Situ, Inc.

2. Measurement/Recording Capability: Water level, temperature, and date and time of day (Data Set).

3. Requirements:

a. Diameter: Not less than 0.72 inches.

b. Length: Not to exceed 8.5 inches.

c. Housing: Sealed within a waterproof Type 316 stainless steel or titanium housing.

d. Measurement and Recording Frequency: Capability to record one Data Set every second.

e. Operating Temperature: 32F to 86F.

f. Pressure Range - Pressure Sensor: Sensitivity range adjustable from minimum of 0 to 30 PSIA to maximum of 0 to 100 PSIA.

g. Accuracy - Pressure Sensor: ±0.1 percent of full scale output or better.

h. Memory: One megabyte of non-volatile memory, or greater.

i. Internal Power: Internal battery shall provide a useful life of not less than 5 years or record not less than 2 million Data Sets during the life of the battery. Battery shall not corrode or leak during its useful life.

j. External Power: Transducer/Data Logger shall be readily adaptable to be powered by an external power supply or battery pack connected to the opposite end of the data cable.

C. In-Situ Rugged Cable System (Non-Vented) – Option Item 107:

1. Manufacturer: In-Situ, Inc.

2. Cable Lengths: As required for installation in each Zone as directed by the Engineer.

3. Requirements:

a. Diameter: Not greater than 0.72 inches.

b. External Cable Material: Teflon, non-volatile material that releases no chemicals to the surrounding environment.

c. Cable Strength: 138 lb minimum break strength.

d. Connector Fittings: Twist-lock connections. Fittings shall be able to support a tensile load of 50 lbs or more. Waterproof to a depth of 700 feet.

2.07 DRILLING EQUIPMENT

A. Drilling Techniques:

1. Air-rotary for the pilot borehole above the water table.

2. Direct mud-rotary or reverse circulation for the pilot borehole below the water table.

3. Direct mud-rotary or reverse circulation for reaming the pilot borehole.

B. Drill Rig Capacity: Able to lift 2 times the weight of the drill string or the length of the well casing assembly, whichever is greater, and able to drill to not less than 1,500 feet.

C. Drill Pipe: In good condition and connected by standard tool or flange-type joints. Reverse rotary drill pipe, if used, shall be a minimum diameter of 6 inches and able to accommodate a flow of not less than 600 gallons per minute (gpm) of drilling mud.

D. Clean and decontaminate the drill rig prior to arriving at each site. Clean the rig and other equipment to the satisfaction of the Engineer prior to the start of drilling.

E. Place a continuous layer of visqueen or similar impervious material beneath the drill rig. Provide an elevated berm or edge for spill containment.

F. Equip with drilling mud measuring equipment conforming to standards of the American Petroleum Institute.

G. Lubricate drill string connections or threads using Teflon, vegetable-based materials, or KOPR-KOTE (lead free) heavy duty drill pipe compound.

2.08 MANAGEMENT OF DRILLING MUD

A. Manage drilling mud properties to ensure removal of drill cuttings from the borehole, recover representative formation samples, maintain borehole stability, and maximize the efficiency of subsequent well development activities.

B. Drilling Mud Characteristics:

1. Weight: 8.7 to 9.2 pounds per gallon (lbs/gal) normal range, not to exceed 9.4 lbs/gal.

2. Maximum Funnel Viscosity: 38 seconds per quart.

3. Maximum 30-Minute Water Loss: 15 cubic centimeters.

4. Maximum Filter Cake: 3/32-inch.

5. Maximum Sand Content of Drill Mud Entering the Borehole: 2 percent by volume.

6. Maximum Total solids content: 8 percent.

7. pH: 8.0 to 9.0 pH units.

8. Reverse circulation drilling methods shall utilize fresh-water based drilling fluid only.

C. Drilling Mud Additives, if used, may include:

1. Baroid Aqua-Gel, Quik-Gel, or other high-grade National Science Foundation (NSF)-certified biodegradable chemical products.

2. Drispac Super Low (Polyanionic Cellulose Polymer).

3. Polymers.

4. Bentonite.

5. Deliver to the drill site in factory labeled and sealed containers for Engineer’s inspection before use.

D. Equipment:

1. Utilize a shale shaker with desanders and desilters, fully capable of handling the volume of the drilling mud and removing drill cuttings.

2. Mud tanks: Adequately baffled to settle drill cuttings and to minimize the re-circulation of silt and clay back into the borehole. Clean tanks as necessary to ensure proper maintenance of drilling mud.

3. Mud tanks and conveyance piping shall be watertight.

E. Tests:

1. Test drilling mud properties hourly and when conditions change. Conduct additional tests as required by the Engineer. Furnish one copy of documented results of each test to the Engineer.

2. Tests on drill mud properties shall conform to ANSI/API RP 13B-1 and include funnel viscosity, weight, sand content, 30-minute water loss, pH, and wall cake thickness.

3. If tests indicate that properties are not within the limits required for Drilling Mud Characteristics, immediately suspend drilling operations and recondition or replace the mud to achieve these standards.

F. Non-Compliant Practices:

1. Drilling with a mixture of water and unprocessed mud, clay, or other material.

2. Brown bag drilling fluid substitutes or organic drilling additives, such as Cellex or CMC.

3. Excavated or below-grade mud pits.

4. If the Engineer determines that drilling mud properties have not been properly controlled, the Contractor may be required to provide a qualified mud engineer to supervise and ensure the maintenance of drilling mud properties.

2.09 MONITORING WELL COVER

A. Borehole Diameter 18 Inches or Less:

1. EMCO Wheaton Retail, Model A0721-218.

   a. Skirt: Heavy Duty, 100 percent welded steel.

   b. Cover: Unpainted, with A0720-001 locking cap and collar, and LADWP Identification Tag.

B. Borehole Diameter 20 Inches or Greater: EMCO Wheaton Retail, Model A0717-124B. Skirt: Heavy Duty, 100 percent welded steel.

PART 3 – EXECUTION

3.01 WET WEATHER EROSION AND SEDIMENT CONTROL PLAN

A. Prevent contamination resulting from construction activities from entering the stormwater.

B. Prevent the spill of drilling mud, development water, and other liquid substances. Immediately contain and clean up spills and notify the Engineer.

C. Prevent the discharge of sediments from portable pumps and hoses by using inlet screens, burlap sacks on hose outlets, sand-bag sediment traps, and control of pump flow rates.

D. Sweep work areas at the end of each work day.

E. Cover drill cuttings and other solid wastes contained on site or in laydown areas.

F. Place drip pans or absorbent materials under equipment.

G. Place and secure geotextile fabric over storm drain inlets potentially affected by any waste stream or storm runoff from the work area.

3.02 CONDUCTOR CASING INSTALLATION

A. Drill a borehole with a diameter directed by the Engineer to a depth not less than 50 feet.

B. Set the conductor casing accurately centered and plumb in the drilled hole.

C. Lap-weld all field joints with not less than 2 passes per circumference. Provide steel guides, attached near the base of and 5 feet below the top of the casing, to center and hold the casing in the proper position until the grout seal is in place.

D. Field weld by the metal-arc method or gas-shielded arc method as described in the AWS “Welding Handbook” as supplemented by other pertinent standards of the AWS. Qualification of welders shall be in accordance with the AWS Standards.

E. Place cement grout in the annular space exterior to the conductor casing. Pump continuously using pressure grouting techniques and a tremie pipe until the annular space is filled to the required depth below ground surface as directed by the Engineer.

F. If the borehole collapses prior to placement of the grout seal, reopen the borehole and place the cement grout seal. Such remedial action shall require the Engineer's approval.

G. Allow cement grout to cure for not less than 12 hours before drilling the pilot borehole below the conductor casing.

H. Obtain soil samples from the conductor casing borehole every 10 feet as directed by the Engineer. Furnish soil samples to the Engineer for laboratory analyses and characterization of the solid waste for disposal purposes.

3.03 PILOT BOREHOLE DRILLING AND GEOPHYSICAL BOREHOLE LOGGING

A. Drill an 8-inch pilot borehole to a depth directed by the Engineer.

1. Use air rotary drilling methods above the water table.

2. Use direct mud rotary drilling methods below the water table.

3. To address noise impacts to surrounding properties, the Engineer reserves the right to issue Change Orders directing the Contractor to immediately discontinue air rotary drilling and to switch drilling methods.

B. Soil Sampling - Option Item 96:

1. Perform soil sampling during the drilling of the pilot borehole using split-spoon sampling equipment and procedures. Collect samples above the water table at elevations directed by the Engineer.

2. Split-spoon soil sampling shall conform to ASTM D 1586-98 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soil."

3. Soil samples: Undisturbed in-situ, not less than 2 inches diameter by 18 inches long per sample.

4. Prior to drilling the pilot borehole, submit a soil sampling plan, including soil sampling equipment and procedures.

C. In-situ Groundwater Sampling - Option Item 97:

1. Obtain undisturbed samples from the formation beneath the pilot borehole using Simulprobe™ sampling equipment and methods.

2. Sampling shall conform to:

a. United States Environmental Protection Agency Groundwater Issues Paper EPA 542-S-02-001 "Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers", (Yeskis and Zavala, May 2002).

b. Manufacturer's written operating procedures.

3. Sample volume: Not less than 3.5 liters per sample.

4. Collect samples at 50-ft intervals starting 5 feet below the water table and continuing to the terminus of the pilot borehole.

5. The Engineer reserves the right to issue Change Orders to obtain additional samples at required locations.

D. Collect and classify representative formation samples at 5-ft intervals throughout the pilot borehole and changes in formation material, color, and sediment type. Prepare drill logs conforming to the requirements of the California Department of Water Resources.

1. Classification of samples shall conform to the Uniform Soil Classification System.

2. Provide sieve analyses of representative samples as directed by the Engineer.

3. Preserve each sample in a heavy duty ziplock plastic bag. Label each bag to indicate the date, time, borehole number, and borehole depth interval. Store samples on site in a manner which prevents damage or loss and is continuously available to the Engineer.

4. Maintain a written log providing the following information:

a. Material types, color, consistency or packing, grain size distribution estimates, and admixtures.

b. Depth and composition of each soil sample processed for sieve analysis.

c. Depth to the top and bottom of each stratification and sieve analysis results per interval.

d. Start and stop times of: Drilling, soil and water sample collection, and geophysical logging. Record drill penetration rates and explanations for any stoppage of the drilling process.

e. Maintain logs on site at all times and furnish 3 copies of the completed logs to the Engineer.

E. Geophysical Logging of the Pilot Borehole:

1. Conduct upon completion of the borehole.

2. Acceptance: Conduct a second set of logs on a repeat section of 100 feet, through a continuous water bearing zone below the water table as directed by the Engineer. If the logs for the repeat section are not identical with the main log for the same region, recalibrate the logging tools and re-log the entire borehole.

3. Record the response curves to show adequate deflections for evaluation of penetrated formations. The vertical scale shall be minimum one inch equals 50 feet for the response curve logs. Furnish the geophysical logs in accordance with Section F01322.

4. Include the following tests:

a. Short Normal Resistivity.

b. Long Normal Resistivity.

c. Single Point Resistivity.

d. Guard Log.

e. Natural Gamma.

f. Spectral Gamma.

g. Spontaneous Potential.

h. Sonic.

i. Deviation and Directional Survey.

j. Caliper Survey.

F. Well Design Furnished by the Engineer:

1. The Engineer will determine the diameter for the reamed borehole and the final well design within 3 working days after the Contractor provides the collection of drill cuttings, sieve analysis, geophysical logs, water quality samples, and driller's logs to the Engineer.

2. The final well design will specify the configuration of the completed well; depth and diameter of the reamed borehole; number of well casings and instruments; and location of well screen intervals, sand filter pack, transition seals, and annular seals.

3. No additional payment will be made for drill rig standby during the geophysical logging or the period provided for the Engineer's design.

G. Prior to reaming, place sealing material of low permeability using a tremie pipe to backfill the bottom section of the pilot borehole to an elevation directed by the Engineer.

H. Borehole Collapse:

1. If the borehole wall collapses, reopen and remove collapsed material where damage has occurred. Immediately notify the Engineer when damage has occurred.

2. Inspect the condition of each well casing and identify the need for repair or replacement of casing segment(s).

3.04 REAM PILOT BOREHOLE AND CONSTRUCT WELL CASINGS

A. Ream to a final diameter and depth as directed by the Engineer.

B. Perform a caliper log and deviation and directional survey of the completed borehole for acceptance by the Engineer. Provide the logs to the Engineer for acceptance of the final borehole condition in accordance with Section F01322.

C. Acceptance: The borehole centerline connecting the borehole center at ground surface to the borehole center at completed depth shall be measured for deviation from a vertical line passing through the center of the conductor casing. This deviation shall be not more than 6 inches per 100 feet of depth. The borehole centerline shall be not less than 6 inches clear from the wall of the reamed borehole at any location.

D. Borehole Collapse:

1. If the borehole wall collapses, reopen and remove collapsed material where damage has occurred. Immediately notify the Engineer when damage has occurred.

2. Inspect the condition of each well casing and identify the need for repair or replacement of casing segment(s).

3.05 WELL CASINGS

A. Install blank well casings and slotted well screens as directed by the Engineer.

B. Install 10 feet of blank well casing below each interval of slotted well screens, fitted with a closed shoe or plug.

C. Install components of the ZIST™ integral with the well casing assembly, including ZIST™ Docking Receiver and surface completion components of the well casing.

D. Install Viton O-ring seals between connected well casing sections within o-ring grove of the flush threaded joints, properly seated without over-stretching the o-ring.

E. Install centralizers:

1. Every 60 feet for blank well casings.

2. Five feet above and 5 feet below each slotted well screen interval.

3. Every 20 feet within the slotted well screen interval.

F. Suspend the well casing string in tension from the surface by means of a landing clamp, and prevent the well casing string from being supported from the bottom.

G. Install well casing assembly continuously using a 24-hour work schedule, from commencement through completion.

H. Obtain the Engineer’s inspection and acceptance of well casing sections prior to installation.

I. Do not use bonding agents or adhesives.

J. As-Constructed Drawings: Furnish a record of each complete well casing assembly installed into each borehole in accordance with Section F01322. The record shall include:

1. Diameter, length, material type, and installed depth of blank well casings and slotted well screens. Include other remarks relevant to well casing materials installed within the borehole.

2. Depth and material composition of sand filter pack, transition seals, annular seals, and sanitary seals.

3. Locations of instruments installed within each casing. Length of installed data cables and sample tubing.

3.06 SAND FILTER PACK, TRANSITION SEAL, ANNULAR SEAL, SANITARY SURFACE SEAL:

A. Sand Filter Pack: Using a tremie pipe, place material from 10 feet below to 10 feet above each interval of slotted well screens.

B. Transition Seal:

1. Place using a tremie pipe above each interval of sand filter pack material to form a bentonite transition seal thickness of not less than 5 feet.

2. Measure the depths to the bottom and top of each interval before and after placement of each bentonite transition seal.

C. Annular Seal:

1. Install below the sanitary surface seal and above and below the intervals of sand filter pack materials and bentonite transition seals.

2. Place continuously until the desired depth is reached for the interval to be grouted.

3. Measure the depths to the bottom and top of each interval before and after placement of the sand-bentonite grout seals.

4. Pump into the annular space using pressure grouting techniques and a tremie pipe. Maintain tremie position at the bottom of the annular space; at no time shall grout material fall freely from the tremie to the elevation where grout material is being placed.

D. Sanitary Surface Seal: Place using a tremie pipe within the interval from the ground surface to 50 feet below ground surface around the well casings.

E. Install sand filter pack, transition seals, and annular seals continuously using a 24-hour per day work schedule, from commencement through completion.

F. Borehole Collapse:

1. If the borehole wall collapses, reopen and remove collapsed material where damage has occurred. Immediately notify the Engineer when damage has occurred.

2. Inspect the condition of each well casing and identify the need for repair or replacement of casing segment(s).

3.07 WELL DEVELOPMENT

A. Perform the following at the direction of the Engineer:

1. Swabbing.

2. Bailing.

3. Air Lifting.

4. Jetting.

5. Chemical Development.

6. Pumping and Surging.

B. General Requirements:

1. Perform well development procedures on each 2-inch and 4-inch well casing completed to each zone.

2. Remove all debris from one-inch piezometer well casings by flushing with potable water, airlifting, and other feasible methods, or as directed by the Engineer.

3. Begin well development procedures not less than 24 hours after sanitary surface seal placement is complete and not later than 72 hours thereafter.

4. Begin each subsequent well development procedure not later than 24 hours after the preceding method is complete.

5. Upon completion of all development operations, demonstrate that the well is clear of all sand, mud, and other foreign material through the bottom of each well casing.

6. Furnish a record of all development work in accordance with Section F01322. Include start time, duration, and observed results of each method utilized.

C. Swabbing and Bailing:

1. Swab Tools: Close-fitting single-swab and double-swab tools with a clearance not to exceed 1/4-inch to the inside wall of the well casing.

2. Bailer: A suction bailer with adequate volume to efficiently remove accumulated material from the base of each well casing.

3. Operate the swabbing tool to develop the full length each slotted well screen using a length of travel in short increments not to exceed 10 feet.

4. Measure the unobstructed depth inside the well casing to determine the level of accumulated sediment and bail or air-lift to remove the sediment to the full depth of the well casing.

5. Acceptance: Until sand and mud washed from the well casing, sand filter, and surrounding formation diminishes to the satisfaction of the Engineer.

D. Development by Air-lifting:

1. Tools: Air compressor with an air line, and inductor pipe and eductor pipe assembly equipped with dual swabs.

2. Operate air-lifting tool over the full length of each slotted well screen in short increments not to exceed 10 feet. Alternately surge and air-lift pump the well. Upon completion, measure the unobstructed depth inside the well casing to determine the level of sediment accumulated in the well. Bail the well casing to remove sediment to the full depth.

3. Acceptance: When the discharge at each interval of 20 feet becomes clear to the satisfaction of the Engineer.

E. Chemical Development:

1. At the direction of the Engineer, introduce a polymer dispersing agent into each slotted well screen at intervals of 20 feet. Agitate the water column, and immediately follow with mechanical development using the double-swab tool.

2. The dispersing agent shall be a solution of Sodium Acid Pyrophosphate (S.A.P.P.), NW-220 or Aqua-Clear PFD.

F. Jetting:

1. Tools: High-pressure jet wash tool with close-fitting single swab capable of continuous rotational and vertical movement and injecting water and chemical mixture; 4 stainless steel nozzles of 3/16-inch diameter and nozzle velocity range of 150 to 250 feet per second.

2. Operate the jet wash tool over the full length of each slotted well screen in increments of approximately one minute per foot of screen until air lift discharge is relatively clear. Remove tool from the bottom of the screen interval at approximately 5 minutes per foot of screen.

3. Utilize potable water for the jetting process. Upon completion, measure the unobstructed depth inside the well casing to determine the level of sediment accumulated in the well. Bail the well casing to remove sediment to the full depth.

4. Acceptance: When the discharge at each interval of 20 feet becomes clear to the satisfaction of the Engineer.

G. Pumping and Surging:

1. Tools: Electrical submersible test pump, discharge column pipe, discharge conveyance piping, wastewater holding tanks, airline for water-level measurement, and flow meter.

a. Flow Meter: An in-line flow meter with 6-digit, straight-reading totalizer, registering in units of 10 gallons, together with a rate-of-flow indicator dial, which reads in units of gallons per minute suitable for the expected flow range.

b. Air Line: Complete with properly calibrated gauge and air pressure supply to measure the depth to water in the well casing during development pumping.

c. Test Pump: Pump capacity range of 5 gpm to 100 gpm against a total head of 500 feet. Disinfect the test pump and discharge column pipe prior to installation.

2. Monitor and record the water levels in the well casings of each zone during the development process at 15-minute intervals.

3. Set the initial pumping rate as directed by the Engineer and gradually increased to the maximum feasible pumping rate. At frequent intervals, discontinue pumping to surge the screen interval until discharge water is clear to the satisfaction of the Engineer.

H. Acceptance: Turbidity in the final water produced from each 2-inch and 4-inch well casing shall not exceed 10 nephelometric turbidity units (NTUs).

1. For testing purposes, discharge water continuously from each 2-inch and 4-inch well casing for 2 hours at a pumping rate of 100 gpm. Measure and record turbidity at 12-minute intervals.

2. The 2-hour discharge test period shall begin after all water quality parameters have stabilized for each well casing.

3. Water quality parameters include pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity.

3.08 PLUMBNESS AND ALIGNMENT SURVEY

A. After completion of well development, demonstrate adequate alignment by lowering into the well a section of pipe 20 feet long and one-half inch smaller diameter than the well casing. The pipe shall run the entire length of the well freely without binding.

3.09 VIDEO SURVEY OF COMPLETED WELLS

A. Provide a color video log of the full depth of each well casing. The camera shall have the capability to provide down-hole and side-scan views without the use of mirrors and without having to remove the camera from the well to change the lenses.

B. Record the log with a screen display constantly indicating the depth of the camera. The video shall be focused and shall clearly display the casing surface from all angles. The video shall be clear and of acceptable quality to the Engineer.

C. Provide a record of the survey on DVD format and a written summary in accordance with Section F01322.

D. Acceptance: Demonstrate that blank well casings and slotted well screens are free of defect and damage and that all sand and debris have been removed from each well casing.

3.10 MONITORING WELL INSTRUMENTATION

A. ZIST™:

1. Option Item 100 through 105: Install Blatypus ZIST™ pumps and water sampling systems inside each 2-inch and 4-inch well casing as directed by the Engineer.

a. System installation shall include ZIST™ Docking Receivers, Viton o-rings, system pressurization and sample-return tubing, perforated drop-tube extensions, volume displacement stems, and other components recommended by BESST, Inc. and accepted by the Engineer.

b. Provide ZIST™ components which reduce groundwater purge volume and enable the extraction of groundwater from the top 20 feet of each well screen interval.

2. System Calibration: Calibrate the Purging Mode and Sampling Mode operating cycles of the Multi Zone Timer Controller for each ZIST™ pump installed. Document the initial calibration of the operating cycles in the Operations and Maintenance manual identifying the as-installed settings for each pump and each well location. Determine the maximum feasible pumping rate of each ZIST™ pump operating within the allowable groundwater drawdown limitation.

3. Performance Testing: Demonstrate the operations of each ZIST™ pumping system to the Engineer for final acceptance. Equipment operations shall conform to United States Environmental Protection Agency “Low Flow (Minimal Drawdown) Ground-water Sampling Procedures” by Puls and Barcelina, April 1996, or as directed by the Engineer.

a. Groundwater Purging and Water Quality Parameter Stabilization: Operate ZIST™ pumps in purge mode to remove groundwater from ZIST™ tubing. Continue pumping in the purge mode to pump groundwater and begin to measure and record water quality indicator parameters. Parameters shall include: pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity. Continue purge-mode discharges until each parameter stabilizes as directed by the Engineer. Record volumes of groundwater discharged from each ZIST™ pump.

b. Groundwater Sample Collection: Operate each ZIST™ pump to produce 40 liters of groundwater from each well screen interval. Discharge groundwater into water quality sample containers provided by the Engineer. Collection of groundwater into sample containers will be handled by the Engineer.

c. Zone Isolation and Groundwater Drawdown Measurements: Measure the elevation of the groundwater surface using transducers and a sounding device before and during each mode of operation to measure the drawdown in each well casing at time intervals directed by the Engineer. Drawdown shall not exceed one inch at any time during the performance test.

4. Acceptance:

a. Demonstrate that ZIST™ system purging, water quality parameter stabilization and sample collection procedures can be successfully completed at each well.

b. Wells containing 3 ZIST™ systems or less: Complete performance tests in not more than one work shift not to exceed 8 hours total.

c. Wells containing 4 ZIST™ systems or greater: Complete performance tests in not more than 2 work shifts not to exceed 16 hours total.

d. Mobilize, demobilize, and reconfigure equipment within the overall time allowed to successfully complete the demonstration.

e. ZIST™ system installations failing the performance test shall be corrected and have the demonstration repeated. Repeated failure of the performance test after 5 attempts shall be grounds for removal of the failed ZIST™ components.

B. In-Situ Level Troll 500 Pressure Transducers and Rugged Cables – Option Items 106 and 107:

1. Install In-Situ Level Troll 500 Pressure Transducers and Rugged Cable System inside each one-inch well casing.

2. Calibrate transducer sensor settings as directed by the Engineer.

3.11 SURFACE COMPLETION

A. Conform to the SSPWC and the additions and supplements of the City of Los Angeles (“Brown Book”).

B. Wellhead Enclosures, Covers, Surface improvements: Construct per Contractor-furnished design approved by the Engineer.

C. Monitoring Well Cover:

1. Provide EMCO Wheaton Retail, Model A0721-218 or EMCO Wheaton Retail A0717-124B as directed by the Engineer.

2. Install a reinforced concrete collar around the manhole skirt, not less than 12 inches wide and 18 inches deep.

D. Install locking water-tight caps on each well casing.

E. Design and install to accommodate storage for and access to ZIST™ tubing. Provide sufficient length of tubing to connect to the ZIST™ Multi-Timer Control Unit without the need for removing the locking caps from the well casings.

F. Design and install to accommodate storage for and access to the In-Situ Rugged Cable System. Provide sufficient length to connect to the In-Situ Rugged Reader without the need for removing the locking caps from the well casings.

3.12 WASTE MANAGEMENT AND DISPOSAL

A. General Requirements:

1. Comply with and implement procedures provided in the following discharge permit guidance documents:

a. Guidance Document for the NPDES Discharge Permit, Number CAG994005, CI-9255 for the Mission Wellfield Groundwater Study Project.

b. Guidance Document for the Industrial Waste Discharge Permit Number W-496163 for Mission Wellfield sanitary sewer as used by the Mission Wellfield Groundwater Study Project.

c. Guidance Document for the Industrial Waste Discharge Permit Number W-208712 for Van Nuys Service Center as used by the Groundwater System Improvement Study (GSIS).

2. Contain and store investigation-derived wastes, including drill cuttings, drilling mud, wastewater, and other wastes.

3. Furnish samples of solid wastes and wastewater to the Engineer. Solid waste samples obtained from temporary containers shall be collected from not less than 3 depths and locations within the container in a manner that is statistically representative of the material(s) being disposed.

4. The Engineer will characterize the wastes for disposal purposes and provide direction for disposal immediately following 7 working days after receiving samples. Hold wastes in temporary containment until the Engineer authorizes disposal.

5. Meter and record discharge volumes, flow rates, dates, and the start and end times of all wastewater discharges.

6. Complete appropriately required waste disposal manifests and bills of lading and submit such documents to the Engineer for signature and approval prior to transporting wastes from the site. Furnish one original waste disposal manifest signed and certified by the disposal facility confirming the volume and receipt of waste materials.

B. Solid Waste Disposal - Option Item 108:

1. Dispose to a permitted waste disposal facility approved by the Engineer.

2. The Engineer anticipates that solid wastes, including drill cuttings and settled solids from the drilling mud, will be classified by lab analysis as non-hazardous waste.

3. Solid wastes classified by lab analysis as hazardous: Contain and dewater for further handling and disposal as directed by the Engineer.

4. The Contractor shall be responsible for handling, cleanup of, testing, removing, and disposing wastes that are contaminated by its activities, and all related costs. This includes completing required waste disposal manifests which shall list the Contractor as the generator of such wastes.

C. Based on waste characterization test results, the Engineer will direct the disposal of wastewater using the following options:

1. Disposal to a permitted facility.

2. Temporary wastewater containment at the Mission Wellfield, located at 12200 Havana Avenue, Sylmar, California, 91342.

3. Disposal to the sanitary sewer.

4. Wastewater treatment at the Mission Wellfield.

5. Disposal to the storm drain system.

D. Option Item 109: Dispose of wastewater to a permitted waste disposal facility accepted by the Engineer.

E. Temporary Wastewater Containment at Mission Wellfield - Option Item 110:

1. Provide not less than 100,000 gallons of temporary wastewater containment.

2. Transport wastewater to Mission Wellfield and discharge into temporary containment.

F. Wastewater Disposal to Sanitary Sewer - Option Items 111 and 112:

1. Dispose wastewater to the sanitary sewer at Mission Wellfield via Contractor-provided wastewater conveyance pipelines and appurtenances (Option Item

111) or LADWP's Van Nuys Service Center (Option Item 112) as directed by the Engineer. Van Nuys Service Center: 14401 Saticoy Street, Van Nuys, California, 91405.

2. Disposal process to the Van Nuys Service Center includes transferring wastewater from temporary containment to vacuum trucks and transporting to the sanitary sewer for release to the Publicly Owned Treatment Works.

3. Industrial Waste Discharge Permit Limits: See Subarticle 3.12J of this Section.

4. Daily discharge limit:

a. Discharges to the Mission Wellfield sanitary sewer shall not exceed 22,500 gallons per day.

b. Discharges to the Van Nuys Service Center sanitary sewer shall not exceed 22,500 gallons per day.

5. Flow rate limit:

a. Discharges to the Mission Wellfield sanitary sewer shall not exceed 45 gpm.

b. Discharges to the Van Nuys Service Center sanitary sewer shall not exceed 100 gpm.

G. Temporary Granular Activated Carbon (GAC) Wastewater Treatment System - Option Items 113 and 114:

1. Design the treatment system to achieve compliance with Discharge Permit Limits. See Subarticle 3.12H of this Section for representative water quality expected for this project. The Engineer will provide wastewater characterization results for the design.

2. Submit a wastewater treatment work plan which includes the equipment, treatment process schematic diagram, chemicals, estimated process flow rate, and operating procedures.

3. Provide temporary GAC wastewater treatment systems at Mission Wellfield, including:

a. Filters.

b. GAC portable treatment units.

c. Baker tank for containing 20,000 gallons of treated effluent.

d. Pumps.

e. Temporary conveyance piping and appurtenances.

f. Flow meters and totalizers.

g. Power generators.

h. Appurtenances for collection of samples from the raw and treated wastewater.

4. Process wastewater and furnish samples of the treated effluent to the Engineer. The Engineer will characterize the treated effluent and provide results immediately following 7 working days. The Engineer will direct the discharge of treated effluent after test results demonstrate compliance with Discharge Permit Limits.

5. Discharge Permit Limits:

a. National Pollution Discharge Elimination System (NPDES) permit for wastewater discharge to the Mission Wellfield storm drain system. See Subarticle 3.12I of this Section.

b. Industrial Waste Permit for wastewater discharge to the sanitary sewer. See Subarticle 3.12J of this Section.

6. Dispose of residual solid waste byproducts from the groundwater treatment as specified in Article 3.12 of this Section.

H. Representative water quality: This list is based on a composite of analyzed groundwater samples obtained from the Mission Wellfield. Treatment systems shall be sufficiently robust to accommodate fluctuations in groundwater quality.

Representative Water Quality		
Constituent	**Concentration**	**Units**
Chloride	48.8	mg/l
Iron	247	ppb
Manganese	18.6	ppb
Nitrate (as NO_3)	36.9	mg/l
Perchlorate	< 4	ppb
Sulphate (SO_4)	142	mg/l
Trichloroethylene (TCE)	9	ppb
Trichloropropane (1,2,3 TCP)	< 0.005	ppb
Total Chromium	4.1	ppb
Total Dissolved Solids (TDS)	485	mg/l
Uranium	3.6	pCi/l
mg/l = milligram per liter		
pCi/l = Picocuries per liter		
ppb = parts per billion or micrograms per liter		

I. National Pollution Discharge Elimination System (NPDES) permit limits for wastewater discharge to the Mission Wellfield storm drain system:

NPDES Permit Discharge Limits – Mission Wellfield Storm Drain System			
Constituent	**Daily Maximum**	**Monthly Average**	**Units**
Total Dissolved Solids	250		mg/l
Sulfate	30		mg/l
Chloride	10		mg/l
Total Suspended Solids	150	50	mg/l
Turbidity	150	50	NTU
BOD_5 @ 20C	30	20	mg/l
Settleable Solids	0.3	0.1	ml/l
Residual Chlorine	0.1		mg/l
Trichloroethylene (TCE)	5.0		ppb
Perchloroethylene (PCE)	5.0		ppb
Perchlorate	6.0		ppb

NPDES Permit Discharge Limits – Mission Wellfield Storm Drain System			
Constituent	**Daily Maximum**	**Monthly Average**	**Units**
1,4 Dioxane	3.0		ppb
Nitrosodimethylamine (NDMA)	5.0		ppb
mg/l = milligram per liter			
ml/l = milliliter per liter			
ppb = parts per billion or micrograms per liter			
NTU = nephelometric turbidity units			

J. Industrial Waste Discharge permit limits in milligrams per liter (mg/L) for wastewater discharges to the sanitary sewer:

Industrial Waste Permit Discharge Limits		
Constituent	**Instantaneous Maximum**	**Units**
Arsenic	3.00	mg/l
Cadmium	15.00	mg/l
Copper	15.00	mg/l
Cyanide (Total)	10.00	mg/l
Cyanide (Free)	2.00	mg/l
Dissolved Sulfides	0.10	mg/l
Lead	5.00	mg/l
Nickel	12.00	mg/l
pH Range	5.50 to 11.00	
Silver	5.00	mg/l
Chromium (Total)	10.00	mg/l
Zinc	25.00	mg/l
Dispersed Oil and Grease	600.00	mg/l
Floatable Oil and Grease	None Visible	mg/l
Temperature	140	F
Semi-Volatile Organic Compounds	1.00	mg/l
Volatile Organic	1.00	mg/l

Industrial Waste Permit Discharge Limits		
Constituent	**Instantaneous Maximum**	**Units**
Compounds		
mg/l = milligram per liter		
F = degrees Fahrenheit		

3.13 SITE CLEANUP

A. Clean up and restore each well drilling site and temporary lay down area to its prior condition.

B. Replace plants, trees, landscape elements, pavement, sidewalk, curb, and gutter affected by the construction. Limits of sidewalk, curb, and gutter replacement will be to the nearest existing joint as directed by the Engineer.

C. Obtain the Engineer’s approval of all submittals, drill logs, as-constructed drawings, and periodic and final reports and test results.

D. File the approved drill logs with the California Department of Water Resources.

3.14 TEMPORARY WELLS IN PILOT BOREHOLE - OPTION ITEMS 98 AND 99

A. At the direction of the Engineer, construct a temporary well inside the pilot borehole at a depth of 500 feet (Option Item 98), 1,000 feet (Option Item 99), and other depths directed by the Engineer. Set a temporary test pump to perform an aquifer zone test at the required depth interval(s).

B. Test pump capacity: Range of 60 to 250 gpm and pumping lift of 400 feet.

C. Zone testing shall include the following:

1. Using a tremie pipe, fill the bottom section of the pilot borehole with grout to a depth approximately 7 feet below the test interval and place a Baroid bentonite transition seal above the sand filter pack in a thickness of not less than 5 feet.

2. Lower a 20-foot perforated pipe section, attached to the bottom of the drill pipe string, into the borehole interval to be zone tested.

3. Place sand filter pack around the perforated section to a depth approximately 2 feet above and below the perforated pipe section and place a second Baroid Bentonite transition seal above the sand filter pack in a thickness of not less than 5 feet.

4. Pump the temporary well using air lift techniques for approximately 3 hours, followed by pumping using a submersible pump lowered into the drill pipe. Pump at a constant rate as directed by the Engineer for approximately 3 hours.

5. Measure and record the water level in the temporary well and the discharge flow rate. Measure pH, temperature, electrical conductivity, and turbidity at 15-minute intervals.

6. Provide a water quality sampling point as near as possible to the well head. As directed by the Engineer, reduce the pumping rate and facilitate the Engineer's collection of water quality samples from the pump discharge.

7. Turn off the pump and measure water levels at regular intervals for 2 hours.

8. Provide a record of the well testing process in accordance with Section F01322.

D. At the completion of each test, raise the drill string and perforated pipe section to the subsequent test interval and construct an additional temporary well as directed by the Engineer.

3.15 AQUIFER PUMP TEST - OPTION ITEM 116

A. Set a temporary submersible pump and discharge piping within the 2-inch or 4-inch well casing as directed by the Engineer to conduct aquifer pump tests.

B. Test pump capacity: Range of 60 to 250 gpm and a pumping lift of 400 feet.

C. Conduct step-rate and constant-rate pump tests as directed by the Engineer.

D. Duration: 40 hours, including mobilization, installation and removal of the temporary pump and discharge pipe, and demobilization.

E. Measure and record the water level in each well, pump discharge rate, totalizing flow, electrical conductivity, pH, temperature, and turbidity of the discharge on the following schedule:

1. First 10 minutes: Every minute.

2. 10 minutes to 120 minutes: Every 10 minutes.

3. 120 minutes to end of test: Every hour.

F. Remove accumulated sediment from the well after completing all pump tests.

END OF SECTION

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Tujunga Monitoring Well Installation
Sampling and Analysis Plan
City of Los Angeles,
Los Angeles County, California

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1.0 INTRODUCTION

The United States Army Corps of Engineers (ACE) has tasked Weston Solutions, Inc. to provide a Technical Approach Document in support of installing four Monitoring Wells in the northeastern San Fernando Valley. The Monitoring Well construction is a key requirement in the design and construction of the City of Los Angeles Department of Water and Power's (LADWP's) proposed Central Purification Complex, a time-critical infrastructure project for providing reliable high quality drinking water to over 1 million people. These monitoring wells will provide data for the aquifer that will be used to determine the size and types of purification methods utilized at each wellhead facility. Data will include parameters such as contaminant concentrations, aquifer stratification, flow rates, and draw-down. In addition, the wells will provide monitoring information for the kinds of contaminants that may impact the wellfield in the future, including the concentrations and expected time frame for intersecting the wellfield, so that the LADWP can conduct changes in the Wellhead Purification System in a timely manner.

This Sampling and Analysis Plan, prepared by WESTON under the direction of the ACE, describes the sampling methods and laboratory analyses that may be conducted during the installation of the Monitoring Wells. The data from these analyses will be used by the LADWP Project Engineer (Engineer) to determine the construction parameters (e.g. screen intervals, number of zones screened, future well placement) of each Monitoring Well. Most of the technical details of the well installation may be found in the Tujunga Monitoring Well Technical Approach document (Weston 2011) and the LADWP Part F: Detailed Specifications document.

Once the wells are installed, the LADWP will conduct formal sampling under State of California, Title 22, State of California Department of Public Health (CDPH) 97-005, and USEPA Safe Drinking Water Act requirements under a separate Sampling and Analysis Plan.

2.0 BACKGROUND

LADWP has 115 water wells, of those 54 are unusable and the remainder of wells are in imminent danger of closure due to increasing levels of contamination from past manufacturing activities, in the San Fernando Valley that have contaminated the groundwater in the San Fernando water Basin (SFB). Included in the 115 wells, the Tujunga Well Field is a series of twelve groundwater production wells installed in the Tujunga Spreading Basin in the early 1990s, located near the intersection of the 170 and I-5 freeways in the northeastern San Fernando Valley, Los Angeles County, California. The wells have an operational capacity of approximately 4,000 gallons per minute each and were installed to offset the loss of water production in the North Hollywood area to the south in the late 1980s due to contamination. LADWP began closing wells in the Tujunga Well Field beginning in April 2002 due to contamination in the groundwater. In short, this scope is prepared to initiate a solution for this critical water supply infrastructure project, and is needed to assure timely completion of the project.

In order to utilize the water from the Tujunga Wellfield, and as part of the Central Purification Complex project; LADWP is planning to install a multi-stage purification facility at the Tujunga and North Hollywood wellfields.

This SAP only covers analyses conducted in support of the Monitoring Well Construction phase. Sampling conducted after the wells are completed will be conducted under a separate, more comprehensive plan.

3.0 SAMPLING OBJECTIVES

The objective of this sampling event is to screen for the presence of contaminants of concern (CoCs) in the soils and/or groundwater during the construction phase of the Monitoring Well installations. This SAP applies to all LADWP Monitoring Wells in the east San Fernando Valley. CoCs include chlorinated solvents, such as perchloroethylene (PCE) and Trichloroethylene (TCE), as well as hexavalent chromium, perchlorate, and 1,4 dioxane. A complete analyte list is presented in Table 3-1, along with appropriate action levels and recommended method detection limits (MDLs).

Table 3-1 Analyte List and Methods

Analysis	Method	MDL (Water)	MDL (Soil)	EPA MCL	CA MCL
VOC	8260B	see below	see below		
1,1 dichloroethane (1,1 DCA)	8260B	0.23	1.3	-	5
1,1 dichloroethene (1,1 DCE)	8260B	0.17	1.6	7	6
cis-1,2 dichloroethene-cis (cis-1,2 DCE)	8260B	0.25	1.3	70	6
trans-1,2 dichloroethene (trans-1,2 DCE)	8260B	0.2	0.8	100	10
carbon tetrachloride	8260B	0.13	1.4	5	0.5
methyl tert-butyl ether (MTBE)	8260B	0.12	2.4	-	13*
tetrachloroethylene (PCE)	8260B	0.16	0.8	5	5
trichloroethylene (TCE)	8260B	0.17	0.7	5	5
Hexavalent Chromium	218.6/7199	0.1ug/L	100ug/kg	-	(0.02)**
1,4-Dioxane	8270SIM	0.60 ug/L	50 ug/kg	-	(1)***
Perchlorate	314	1.00 ug/L	10 ug/kg	-	6

MDL = Method Detection Limit

EPA MCL = US Environmental Protection Agency Maximum Contaminant Limit for Drinking Water

CA MCL = State of California Title 22 Maximum Contaminant Limit for Drinking Water

CA PHG = State of California draft Public Health Goal for hexavalent chromium in drinking water (December 2010 OEHHA).

* The primary CA MCL for MTBE is 13 ug/L; the secondary CA MCL is 5 ug/L

** There is no CA MCL for this analyte; the value reported is the State of California draft Public Health Goal for hexavalent chromium in drinking water (December 2010 OEHHA).

*** There is no CA MCL for this analyte; the value reported is the State of California Department of Public Health Notification Level.

The data will be used to identify soil and water-bearing zones with the greatest concentrations of contaminants. These data, along with geological and down-hole geophysical logs from the boring hole, will be used by the Engineer to most effectively place the well screen intervals and sanitary seals on each Monitoring Well. The generalized methodology for determining the well construction parameters is discussed in Section 5.3.2 below, as well as the Tujunga Monitoring Well Technical Approach and the LADWP Part F: Detailed Specifications documents. The LADWP Project Engineer will use best practices and professional judgment in reviewing these data to determine the final disposition of the wells.

4.0 DATA QUALITY OBJECTIVES

The Data Quality Objective (DQO) process, as set forth in the EPA document, *Guidance for the Data Quality Objectives Process,* EPA QA/G-4, was followed to establish the data quality objectives for this project. An outline of the process and the outputs for this project are included in Appendix A.

This investigation will involve the generation of definitive data for soil and groundwater. The specific requirements for this data category are detailed in Section 9. The data generated under this project will comply with the requirements for that data category as defined in *Data Quality Objective Process for Superfund*, EPA 540/G-93/71, September 1993. All definitive analytical methods employed for this project will be methods approved by the EPA.

For soil, the Engineer may choose to direct the driller to collect core samples in a manner consistent with EPA SOP #2012 in unsaturated soils to determine whether contamination from nearby sources has impacted the location. Action levels in soil will be the Method Detection Limit (MDL), as these CoCs are not naturally occurring at concentrations above the detection range.

For groundwater, the Engineer may choose to collect grab samples when groundwater is first encountered, and at subsequent 50-foot intervals to establish a vertical contaminant profile. Samples will be analyzed for CoCs (see Table 3-1) by an LADWP laboratory (or its contract facility) with the most expedient turnaround time practicable. The highest priority analytes are TCE, PCE, and hexavalent chromium, with the remaining VOCs, perchlorate, and 1,4 dioxane being of secondary concern. The LADWP has determined that the action level should be the lower of Federal or State of California Maximum Contaminant Levels (MCL). The MDL should be at least half of the action level.

Individual samples, QA samples, sample methods, sample containers, and preservatives are indicated in Table 4-1.

Table 4-1: Request for Analysis

Analysis		VOC	Cr6	1,4-Dioxane	Perchlorate
Method		8260B	218.6/7199	8270SIM	314
Water Matrix	**Volume Sample**	4 x 40mL	250 mL	2 x 1L	125mL
	Sample Containers	40 mL glass vials with septa lid	250 ml poly bottle	1 L Amber glass bottles	HPDE or Glass bottles
	Preservative	HCl preservation, No headspace in vials, Cool 4°C	ammonium sulfate/hydroxide buffer, Cool 4°C	Cool 4°C	Cool 4°C
	Holding Time	14 day holding time	24 hours**	7 days Extract/40 days analysis after extraction	28 day holding time
	Estimated No. of Water Samples (per well)	15	15	15	15
Soil Matrix	**Volume Sample**	3 x 5 g	8 oz	4 oz	2 oz
	Sample Containers	5-gram Encore Sampler	glass jar	glass jar	glass jar
	Preservative	Cool 4°C	Cool 4°C	Cool 4°C	Cool 4°C
	Holding Time	48 hours	30 days	40 days	28 days
	Estimated No of Soil Samples (per well)	6	6	6	6

Total Sample Volume for Water Samples: approx. 3 L

Estimated number of samples includes duplicate samples (one duplicate per ten samples).

** 24 hour holding time for Cr6 water analysis if not preserved with ammonium sulfate/hydroxide buffer
Each soil VOC sample requires three 5-gram Encore containers.
Each water VOC sample requires four 40ml septa vials.

5.0 FIELD METHODS AND PROCEDURES

5.1 Soil Sampling

5.1.1 Split-Spoon Sampling Procedures

In conformance with ERT Soil Sampling Guidance (ERT SOP #2012), a clean, eighteen-inch split-spoon sample tube with brass sleeves will be advanced via the drill rig wire line through the conductor casing. Blow counts for each six-inch interval will be called off by the driller and the geologist will log these data. The split-spoon sample tube will be brought to the surface and opened for the geologist's inspection.

5.1.2 Obtaining Samples

Upon inspection, the geologist will collect three Encore™ sample containers at the interval specified by the Engineer. Samples should be biased toward finer-grained lithologies, should any stratification be present. The samples will be capped, labeled, and immediately placed on ice. An additional four-ounce volume will be collected for dry weight calculation. Once the sample has been preserved, the geologist may log the remaining core. Sample container and preservative requirements are presented in Table 4-1. Upon preservation and storage of the samples, information for each sample will be recorded in the logbook and on a chain of custody form.

5.2 Groundwater Sampling

5.2.1 Simulprobe™ Procedures

Groundwater grab samples will be collected in accordance with Superfund Groundwater Sampling Guidance (EPA 542-S-02-001) and Simulprobe™ standard operating procedures. A nitrogen-charged Simulprobe™ sampler is lowered into the conductor casing to the appropriate depth using the drill rig wire line. The sampler is hammered into the bottom of the borehole, below the drill bit. The upper sheath pulls back as the sampler is driven into the strata. The sampler is pulled back four inches to expose the screen at the base of the core sample. The nitrogen atmosphere is evacuated via surface controller; the nitrogen in the sampler is replaced by groundwater, which flows into the sample canister. The sampler is re-charged with nitrogen and pulled to the surface.

5.2.2 Obtaining Samples

Pre-preserved sample bottles will be filled from the Simulprobe™ sampler. The VOC sample bottles will be filled first, followed by the hexavalent chromium samples, followed by the perchlorate samples. Samples for 1,4 dioxane analyses will be collected last, and the Engineer may decide not to collect the 1,4 dioxane samples if time/sample volumes are not sufficient. The bottles will be labeled and placed on ice. Sample bottle and preservative requirements are presented in Table 4-1 as well as the analytical holding times. Upon preservation and storage of the samples, information for each sample will be recorded in the logbook and on a chain of custody form. The samples will be handed off to an LADWP courier, who will deliver the samples to the laboratory as soon as practicable (on the same day as sample collection). The samples will be analyzed with a 24-hour turnaround time.

5.3 Determination of Well Construction Parameters

The Engineer will use the data collected under this SAP to determine the well construction parameters. The well construction parameters may include:

- Completing the well in one, two, or three water-bearing zones.
- The depth of each zone screened.
- The thickness of the sanitary seal.
- Whether the boring should be abandoned, and the well constructed at another location.

The determination of these factors will be based in part on chemical data collected under this SAP, as well as geologic and geophysical data collected during the Pilot Boring phase. The overall end-use of these data is described in Tujunga Monitoring Well Technical Approach document (Weston 2011) and the LADWP Part F: Detailed Specifications documents. Specific data use objectives are outlined below, as well as in Appendix A: Data Quality Objectives.

5.3.1 Use of Soil Analyses Results

The use of soil data for this stage of the well construction is laid out in Appendix A: Data Quality Objective No. 1. Soil analyses will be used primarily to determine whether COCs are present in the soils through which the well is constructed. The presence of COCs in the soil column may cause the Engineer to consider installing a sanitary seal through the contaminated zone in order to ensure that the annular space does not become a conduit for contaminants to groundwater. In addition, these data may be useful in the on-going investigation into the source area for the groundwater pollution problem in the area.

5.3.2 Use of Groundwater Results

The use of groundwater data for this stage of the well construction is laid out in Appendix A: Data Quality Objective No. 2. Groundwater analytical data will be collected at regular intervals through the water-bearing zone to determine concentrations of COCs at these intervals.

The data will be plotted along with the geologic log so that the Engineer may make determinations about whether the contractor should continue drilling the Pilot Boring to the design depth, cease drilling and install the well in a shallow configuration, or drill deeper to investigate conditions at depths greater than the initial design depth. One example of where the Engineer may choose to cease drilling and install the well in shallow groundwater would be in a situation where either COCs are not detected in the water column, or COCs are detected in shallow water, but concentrations dissipate to non-detect levels with depth. One example of where the Engineer might chose to drill deeper than the design depth would be where COCs are detected at increasing concentrations in the deepest levels of the design depth.

Once the Pilot Boring is drilled to total depth, the field team will conduct a geophysical survey of the borehole to assist with determining where the highest zones of hydrologic conductivity occur. The geophysical survey may include:

- Long and Short normal resistivity.
- Point Resistivity

- Guard log
- Natural Gamma
- Spectral Gamma
- Spontaneous Potential
- Sonic
- Directional Drilling
- Caliper Surveys

The Engineer may choose to conduct one or a number of geophysical tests to assist with installing the well screen(s) at the appropriate depth. The well screen should be installed in lithologies that exhibit medium- to coarse-grain clasts that will not infiltrate the sand pack or well screen slot width. The well should not be screened across any clay, silt, or fine sand that might infiltrate and cause degradation of water quality.

5.4 QA Samples

One blind duplicate sample will be collected per matrix for every ten field samples collected. Duplicate samples will have a unique sample name and will be collected as a distinct sample. The corresponding field sample will be recorded in the logbook, but not reported to the laboratory.

One matrix spike/mean spike duplicate (MS/MSD) sample per matrix will be submitted for every twenty (20) field samples. A Matrix Spike and Spike Duplicate (MS/MSD) sample is a representative, but randomly chosen sample that has known concentrations of analytes of interest added to the samples prior to sample preparation and analysis. They are processed along with the same un-spiked sample. The purpose of the MS/MSD is to document the accuracy and precision of the method for that specific sample. The MS/MSD sample will require additional volume, but will have the same sample name as the field sample. The MS/MSD designation will be reported to the laboratory.

A trip blank will be included with any sample delivery that includes samples from multiple zones. The trip blank will consist of an appropriate number of sample bottles filled with distilled or laboratory-grade water. The trip blanks will be given a sample name in the sequence “Well Number”-“Trip”-“Date,” such that a trip blank prepared to accompany a set of samples from TJ-MW-08 on August 12, 2011 will have the name, “TJ-MW-08-TRIP-8-12-2011.” The trip blank will be analyzed for all CoCs, and the data will be used as a measure of cross contamination during shipping. Although trip blanks are not necessary when only one sample is shipped, the Engineer may choose to include a trip blank as an overall sampling method blank.

No equipment blank will be collected as only dedicated equipment will be used.

5.5 Decontamination

Dedicated equipment will be used during water sampling; therefore, no decontamination will be required.

6.0 DISPOSAL OF INVESTIGATION-DERIVED WASTE

Used gloves and sample canisters will be double-bagged and disposed of as municipal waste. Soil waste will be co-mingled with drill cuttings in roll-off bins, which will be profiled and properly disposed of based on the profile data. Purge water will be drummed and stored in the yard area pending waste profiling. This water may be co-mingled with well development water produced by the same well. No other investigation-derived waste is anticipated.

7.0 SAMPLE DOCUMENTATION AND SHIPMENT

7.1 Sample Documentation

All sample documents will be completed legibly, in ink. Any corrections or revisions will be made by lining through the incorrect entry and by initialing the error.

7.1.1 Field Logbook

The field logbook is essentially a descriptive notebook detailing site activities and observations so that an accurate account of field procedures can be reconstructed in the writer's absence. All entries will be dated and signed by the individuals making the entries, and will include the following:

1. Site name and project number.
2. Names of personnel on site.
3. Dates and times of all entries in military time.
4. Descriptions of all site activities, including site entry and exit times.
5. Site events and discussions.
6. Weather conditions.
7. Site observations.
8. Identification and description of samples and locations.
9. Date and time of sample collections, along with chain of custody information.
10. Record of photographs.
11. Site sketches.

7.1.2 Sample Labels

Sample labels will clearly identify the particular sample, and will include the following:

1. Site name.
2. Time and date sample was taken.
3. Sample identification number.
4. Sample preservation.
5. Analysis requested.

Sample labels will be securely affixed to the sample container.

7.1.3 Chain of Custody Record

A Chain of Custody record will be maintained from the time the sample is taken to its final deposition. Every transfer of custody must be noted and signed for, and a copy of this record kept by each individual who has signed. When samples are not under direct control of the individual responsible for them, they must be stored in a container sealed with a Custody Seal.

The Chain of Custody record should include (at minimum) the following:

1. Sample identification number.
2. Sample matrix.
3. Sample location.
4. Sample date and time.
5. Names(s) and signature(s) of sampler(s).
6. Signature(s) of any individual(s) with control over samples.
7. Analysis type required.
8. Data package requirements.
9. Project account number.
10. Name, address, and phone number of the individual designated to receive results, data package, and invoice.

7.1.4 Custody Seals

Custody Seals demonstrate that a sample container has not been tampered with, or opened. The individual in possession of the samples will sign and date the seal, affixing it in such a manner that the container cannot be opened without breaking the seal. The name of this individual, along with a description of the sample packaging, will be noted in the field book.

7.2 Sample Handling and Shipment

Samples will be placed in a sturdy cooler with hard plastic inside. The following packaging procedures will be followed:

1. Secure the drain plug of the cooler with tape to prevent melting ice from leaking out of the cooler;
2. Line the bottom of the cooler with bubble wrap to prevent breakage during shipment;
3. Check screw caps for tightness
4. Secure bottle/container tops with tape and custody seal all container tops;
5. Affix sample labels onto the containers with clear tape;
6. Place VOA's in a foam holder to prevent breakage; and
7. Seal all sample containers in heavy-duty plastic bags.

Samples will be handed over to an LADWP courier who will deliver the samples to the LADWP laboratory for analyses.

7.3 Schedule of Activities

Samples will be collected during the Pilot Boring phase of Monitoring Well installation. It is currently anticipated that the first four of these wells will be installed between May 1, 2011, and January 31, 2012. Additional wells are expected to be installed over the next two to three years.

Upon mobilization to each drill site, the contractor will present a Pilot Boring schedule to the Engineer, who will then decide whether samples will be collected. The contractor will notify the Engineer at least 24 hours before sampling occurs, including the total number and matrices of samples to be collected and the approximate time samples will be collected.

The laboratory will conduct the analyses on an as-soon-as-possible schedule, because the Engineer may use these data to revise the drilling schedule.

8.0 QUALITY ASSURANCE REQUIREMENTS

8.1 Analytical and Data Package Requirements

It is required that all samples be analyzed in accordance with the methods listed in Tables 3-1 and 4-1. The laboratory is required to supply documentation to demonstrate that their data meet the requirements specified in the EPA Method.

The data validation package shall include copies of all original documentation generated in support of this project. In addition, the laboratory will provide original documentation to support that all requirements of the methods have been met. This includes, but is not limited to, sample tags, custody records, shipping information, sample preparation/extraction records, and instrument printouts such as mass spectra. Original documentation will be retained by the LADWP; copies of the documentation required can be made available on request.

8.2 Data Validation

Data validation of analytical data generated by the LADWP will be conducted in accordance with the EPA *Region 9 Superfund Data Evaluation/Validation Guidance R9QA/006.1* (EPA 2001). Data validation will be conducted by the LADWP either by an independent contractor or a qualified LADWP laboratory manager. Tier 3 Validation for up to 100% of the data will be required, based on the LADWP Engineer’s cursory review of the data. Baring the engineer’s finding any significant issues with the data, a 10% validation will suffice.

To meet requirements for categorization as definitive data, the following criteria will be evaluated:

Holding times
Sampling design approach
Blank contamination
Initial and continuing calibration
Detection limits
Analyte identification and quantitation
Matrix spike recoveries
Performance evaluation samples when specified
Analytical and total error determination
Laboratory Control Samples.

Upon completion of validation, data will be classified as one of the following: acceptable for use without qualifications, acceptable for use with qualifications, or unacceptable for use.

Attachment A: Data Quality Objectives Worksheet

APPENDIX A

SITE-SPECIFIC DATA QUALITY OBJECTIVES

DATA QUALITY OBJECTIVE NO. 1
Monitoring Well Installation
MEDIA OF CONCERN: SOIL

STEP 1. STATE THE PROBLEM	
Contamination may be present in the native soils at the boring location.	
STEP 2. IDENTIFY THE DECISION	
Soil core samples may be collected at depths specified by the LADWP Engineer and submitted for COC analyses.	
IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.	• If COCs are identified in site soils, the Engineer may choose to install engineering controls (such as a thicker sanitary seal) to ensure that the well backfill does not become a conduit for contaminants. The data may be useful in a regional PRP search. • If no COCs are identified in site soils, then the Engineer may choose to install the well as designed.
STEP 3. IDENTIFY INPUTS TO THE DECISION	
IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.	• Boring logs. • Contaminant concentrations in soil samples collected during sampling.
IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.	• Core samples collected at intervals determined by the Engineer. • Analytical results from soil analyses by SW846 Method 8260 or 524.2.
BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.	The COCs are not present in nature, therefore the analytical detection limit is the Action Level.
IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.	• EPA Method 8260B for VOCs • EPA Method 218.6/7199 for hexavalent chromium • EPA Method 314 for perchlorate • EPA Method 8270SIM for 1,4 dioxane
STEP 4. DEFINE THE BOUNDARIES OF THE STUDY	
DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.	Soil in the Pilot Boring column at sampling depth.
SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.	Contaminant concentrations in soils samples.
DEFINE THE SCALE OF DECISION MAKING.	Results of soil samples will be used to determine whether contaminants are present in the soil column above groundwater sampling locations.
DETERMINE THE TIME FRAME TO WHICH THE DATA APPLY.	The data will apply until the soil represented by the sample receives appropriate response actions.

DATA QUALITY OBJECTIVE NO. 1
Monitoring Well Installation
MEDIA OF CONCERN: SOIL

STEP 4. DEFINE THE BOUNDARIES OF THE STUDY (Continued)	
DETERMINE WHEN TO COLLECT DATA.	Samples will be collected during the Pilot Boring phase of well installation.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Inclement weather. • Low sample recovery.
STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETER THAT CHARACTERIZES THE POPULATION OF INTEREST.	Detection of COCs in the soil samples by analytical testing to confirm the presence hazardous substances that may migrate (or may have migrated) to groundwater.
SPECIFY THE ACTION LEVEL FOR THE DECISION.	If the COCs are detected above the analytical detection limit in the soil samples, then COCs are present in soil above the groundwater monitoring location. If the COCs are not detected above the analytical detection limit in the soil samples, then COCs are not present in soil above the groundwater monitoring location.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DEVELOP A DECISION RULE.	If COC is present in soil, then the Engineer may choose to construct engineering controls to deter contaminant migration. The data may also be used to correlate the presence of COCs in soil with COCs in underlying groundwater.
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	Contaminant concentrations may range from 0.5 µg/mg to more than the contaminant specific action level.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	Type I Error: Deciding that the specified area represented by the soil sample does not exceed the specified assessment level when, in truth, the waste soil concentration of the contaminant exceeds its specified assessment level. The consequence of this decision error is that may migrate to groundwater, possibly endangering human health and the environment. This decision error is more severe. Type II Error: Deciding that the specified area represented by the soil sample does exceed the specified assessment level when, in truth, it does not. The consequences of this decision error are that engineering controls may be installed and unnecessary costs will be incurred.

ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the soil is decided to be below the specified assessment levels when in fact, it is not below the specified assessment levels, is that the groundwater may be threatened by overlying soils. The true state of nature when the waste soil is decided to be above the specified assessment levels when in fact, it is not above the specified assessment levels, is that groundwater is not threatened by overlying soils.

DATA QUALITY OBJECTIVE NO. 1
Monitoring Well Installation
MEDIA OF CONCERN: SOIL

STEP 6. SPECIFY LIMITS ON DECISION ERRORS (Continued)	
DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	Ho: The soil represented by the sample is above the specified action level. Ha: The soil represented by the sample is below the specified action level.
ASSIGN THE TERMS "FALSE POSITIVE" AND "FALSE NEGATIVE" TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II
ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	Results of each sample will be considered to be representative of the strata from which it was collected. No statistical analysis will be conducted.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	The data may be compared with results from overlying, or underlying, strata in order to determine contaminant migration and/or actual threat to groundwater.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. Samples will be collected at the direction of the Engineer to evaluate the presence of COCs in the soil column. The most likely scenario is the collection of soil samples using a split-spoon sampler at 10 foot intervals through the first 50 feet of the boring, unless data exist to collect more samples or at different intervals.	

DATA QUALITY OBJECTIVE NO. 2
Monitoring Well Installation
MEDIA OF CONCERN: GROUNDWATER

STEP 1. STATE THE PROBLEM	
Contamination may be present in stratified groundwater zones at the boring location.	
STEP 2. IDENTIFY THE DECISION	
Groundwater grab samples may be collected at depths specified by the LADWP Engineer and submitted for COC analyses.	
IDENTIFY THE ALTERNATIVE ACTIONS THAT MAY BE TAKEN BASED ON THE DECISIONS.	• If COCs are identified in groundwater at a given elevation in the water column, the Engineer may design a nested well configuration with a screen at the zone of highest concentrations, as well as lower elevations where contaminants are present, or future water quality may be threatened. • If no COCs are identified in groundwater at the specified interval, then the Engineer may choose to screen the screen the well in a different zone.
STEP 3. IDENTIFY INPUTS TO THE DECISION	
IDENTIFY THE INFORMATIONAL INPUTS NEEDED TO RESOLVE A DECISION.	• Boring logs. • Contaminant concentrations in depth-specific groundwater grab samples collected during sampling.
IDENTIFY THE SOURCES FOR EACH INFORMATIONAL INPUT AND LIST THE INPUTS THAT ARE OBTAINED THROUGH ENVIRONMENTAL MEASUREMENTS.	• Depth-specific groundwater grab samples collected at intervals determined by the Engineer. • Analytical results from water analyses.
BASIS FOR THE CONTAMINANT SPECIFIC ACTION LEVELS.	The COCs are not present in nature, therefore the analytical detection limit is the Action Level. The analytical detection limit should be as low as technically possible, and at least 0.5 times lower than the MCL.
IDENTIFY POTENTIAL SAMPLING TECHNIQUES AND APPROPRIATE ANALYTICAL METHODS.	• EPA Method 8260B for VOCs • EPA Method 218.6/7199 for hexavalent chromium • EPA Method 314 for perchlorate • EPA Method 8270SIM for 1,4 dioxane
STEP 4. DEFINE THE BOUNDARIES OF THE STUDY	
DEFINE THE DOMAIN OR GEOGRAPHIC AREA WITHIN WHICH ALL DECISIONS MUST APPLY.	Groundwater at a specified elevation in the water column.
SPECIFY THE CHARACTERISTICS THAT DEFINE THE POPULATION OF INTEREST.	Contaminant concentrations in groundwater samples.
DEFINE THE SCALE OF DECISION MAKING.	Results of groundwater samples will be used to determine whether contaminants are present in the groundwater column.
DETERMINE THE TIME FRAME TO WHICH THE DATA APPLY.	The data will apply until the well is completed and sampled under a separate plan.

DATA QUALITY OBJECTIVE NO. 2
Monitoring Well Installation
MEDIA OF CONCERN: GROUNDWATER

STEP 4. DEFINE THE BOUNDARIES OF THE STUDY (Continued)	
DETERMINE WHEN TO COLLECT DATA.	Samples will be collected during the Pilot Boring phase of well installation.
IDENTIFY PRACTICAL CONSTRAINTS ON DATA COLLECTION.	• Inclement weather. • Low sample recovery.
STEP 5. DEVELOP A DECISION RULE	
SPECIFY THE PARAMETER THAT CHARACTERIZES THE POPULATION OF INTEREST.	Detection of COCs in the groundwater samples by analytical testing to confirm the presence hazardous substances.
SPECIFY THE ACTION LEVEL FOR THE DECISION.	If the COCs are detected above the analytical detection limit in the groundwater samples, then COCs are present in groundwater at that specified elevation. If the COCs are not detected above the analytical detection limit in the groundwater samples, then COCs are not present in groundwater at that specified elevation.
STEP 6. SPECIFY LIMITS ON DECISION ERRORS	
DEVELOP A DECISION RULE.	If COC is present in groundwater, then the Engineer may construct a concentration profile to determine the most optimum construction of the Monitoring Well.
DETERMINE THE POSSIBLE RANGE OF THE PARAMETER OF INTEREST.	Contaminant concentrations may range from 0.5 µg/mg to more than the contaminant specific action level.
DEFINE BOTH TYPES OF DECISION ERRORS AND IDENTIFY THE POTENTIAL CONSEQUENCES OF EACH.	Type I Error: Deciding that the specified area represented by the groundwater sample does not exceed the specified assessment level when, in truth, the groundwater concentration of the contaminant exceeds its specified assessment level. The consequence of this decision error is that the well design may not be optimal, and a potential zone of contamination may not be monitored. This decision error is more severe. Type II Error: Deciding that the specified area represented by the groundwater sample does exceed the specified assessment level when, in truth, it does not. The consequences of this decision error are that the well may be screened in a zone that does not require monitoring and unnecessary costs will be incurred.
ESTABLISH THE TRUE STATE OF NATURE FOR EACH DECISION RULE.	The true state of nature when the groundwater is decided to be below the specified assessment levels when in fact, it is not below the specified assessment levels, is that a contaminated water zone may not be monitored. The true state of nature when the groundwater is decided to be above the specified assessment levels when in fact, it is not above the specified assessment levels, is that the well may be constructed in a zone that poses no threat to drinking water.

DATA QUALITY OBJECTIVE NO. 2
Monitoring Well Installation
MEDIA OF CONCERN: GROUNDWATER

STEP 6. SPECIFY LIMITS ON DECISION ERRORS (Continued)	
DEFINE THE TRUE STATE OF NATURE FOR THE MORE SEVERE DECISION ERROR AS THE BASELINE CONDITION OR THE NULL HYPOTHESIS (H_o) AND DEFINE THE TRUE STATE FOR THE LESS SEVERE DECISION ERROR AS THE ALTERNATIVE HYPOTHESIS (H_a).	Ho: The groundwater represented by the sample is above the specified action level. Ha: The groundwater represented by the sample is below the specified action level.
ASSIGN THE TERMS “FALSE POSITIVE” AND “FALSE NEGATIVE” TO THE PROPER DECISION ERRORS.	• False Positive Error = Type I • False Negative Error = Type II
ASSIGN PROBABILITY VALUES TO POINTS ABOVE AND BELOW THE ACTION LEVEL THAT REFLECT THE ACCEPTABLE PROBABILITY FOR THE OCCURRENCES OF DECISION ERRORS.	Results of each sample will be considered to be representative of the strata from which it was collected. No statistical analysis will be conducted.
STEP 7. OPTIMIZE THE DESIGN	
REVIEW THE DQOs.	The data may be compared with results from overlying and/or underlying elevations from the same boring in order to construct a contaminant profile in the water column. These data will be used, along with geologic and geophysical boring logs, to determine the final well construction parameters, including the number of zones monitored and the screen intervals.
DEVELOP GENERAL SAMPLING AND ANALYSIS DESIGN. Samples will be collected at the direction of the Engineer to evaluate the presence of COCs in the groundwater column. The most likely scenario is the collection of groundwater grab samples using a Simulprobe™ sampler at the water table (first water), then at 50 foot intervals through the total depth of the boring, unless data exist to collect more samples or at different intervals.	

Attachment B: Standard Operating Procedures

GENERAL FIELD SAMPLING GUIDELINES

SOP#: 2001
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide general field sampling guidelines that will assist REAC personnel in choosing sampling strategies, location, and frequency for proper assessment of site characteristics. This SOP is applicable to all field activities that involve sampling.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sampling is the selection of a representative portion of a larger population, universe, or body. Through examination of a sample, the characteristics of the larger body from which the sample was drawn can be inferred. In this manner, sampling can be a valuable tool for determining the presence, type, and extent of contamination by hazardous substances in the environment.

The primary objective of all sampling activities is to characterize a hazardous waste site accurately so that its impact on human health and the environment can be properly evaluated. It is only through sampling and analysis that site hazards can be measured and the job of cleanup and restoration can be accomplished effectively with minimal risk. The sampling itself must be conducted so that every sample collected retains its original physical form and chemical composition. In this way, sample integrity is insured, quality assurance standards are maintained, and the sample can accurately represent the larger body of material under investigation.

The extent to which valid inferences can be drawn from a sample depends on the degree to which the sampling effort conforms to the project's objectives. For example, as few as one sample may produce adequate, technically valid data to address the project's objectives. Meeting the project's objectives requires thorough planning of sampling activities, and implementation of the most appropriate sampling and analytical procedures. These issues will be discussed in this procedure.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected, and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling, and storage for air and waste samples are discussed in the specific SOPs for air and waste sampling techniques.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The nature of the object or materials being sampled may be a potential problem to the sampler. If a material is homogeneous, it will generally have a uniform composition throughout. In this case, any sample increment can be considered representative of the material. On the other hand, heterogeneous samples present problems to the sampler because of changes in the material over distance, both laterally and vertically.

Samples of hazardous materials may pose a safety threat to both field and laboratory personnel. Proper health and safety precautions should be implemented when handling this type of sample.

Environmental conditions, weather conditions, or non-target chemicals may cause problems and/or interferences when performing sampling activities or when sampling for a specific parameter. Refer to the specific SOPs for sampling techniques.

5.0 EQUIPMENT/APPARATUS

The equipment/apparatus required to collect samples must be determined on a site specific basis. Due to the wide variety of sampling equipment available, refer to the specific SOPs for sampling techniques which include lists of the equipment/apparatus required for sampling.

6.0 REAGENTS

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

7.0 PROCEDURE

7.1 Types of Samples

In relation to the media to be sampled, two basic types of samples can be considered: the environmental sample and the hazardous sample.

Environmental samples are those collected from streams, ponds, lakes, wells, and are off-site samples that are not expected to be contaminated with hazardous materials. They usually do not require the special handling procedures typically used for concentrated wastes. However, in certain instances, environmental samples can contain elevated concentrations of pollutants and in such cases would have to be handled as hazardous samples.

Hazardous or concentrated samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, or areas previously identified as contaminated, and require special handling procedures because of their potential toxicity or hazard. These samples can be further subdivided based on their degree of hazard; however, care should be taken when handling and shipping any wastes believed to be concentrated regardless of the degree.

The importance of making the distinction between environmental and hazardous samples is two-fold:

(1) Personnel safety requirements: Any sample thought to contain enough hazardous materials to pose a safety threat should be designated as hazardous and handled in a manner which ensures the safety of both field and laboratory personnel.

(2) Transportation requirements: Hazardous samples must be packaged, labeled, and shipped according to the International Air Transport Association (IATA) Dangerous Goods Regulations or Department of Transportation (DOT) regulations and U.S. EPA guidelines.

7.2 Sample Collection Techniques

In general, two basic types of sample collection techniques are recognized, both of which can be used for either environmental or hazardous samples.

Grab Samples

A grab sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

Composite Samples

Composites are nondiscrete samples composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

Compositing is often used for environmental samples and may be used for hazardous samples under certain conditions. For example, compositing of hazardous waste is often performed after compatibility tests have been completed to determine an average value over a number of different locations (group of drums). This procedure generates data that can be useful by providing an average concentration within a number of units, can serve to keep analytical costs down, and can provide information useful to transporters and waste disposal operations.

For sampling situations involving hazardous wastes, grab sampling techniques are generally preferred because grab sampling minimizes the amount of time sampling personnel must be in contact with the wastes, reduces risks associated with compositing unknowns, and eliminates chemical changes that might occur due to compositing.

7.3 Types of Sampling Strategies

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling.

Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site. Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established. When judgmental sampling is performed, samples are collected only from the portion(s) of the site most likely to be contaminated. Often, a combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, the level/type of information desired, etc.

7.4 QA Work Plans (QAWP)

A QAWP is required when it becomes evident that a field investigation is necessary. It should be initiated in conjunction with, or immediately following, notification of the field investigation. This plan should be clear and concise and should detail the following basic components, with regard to sampling activities:

- Objective and purpose of the investigation.
- Basis upon which data will be evaluated.
- Information known about the site including location, type and size of the facility, and length of operations/abandonment.
- Type and volume of contaminated material, contaminants of concern (including concentration), and basis of the information/data.
- Technical approach including media/matrix to be sampled, sampling equipment to be used, sample equipment decontamination (if necessary), sampling design and rationale, and SOPs or description of the procedure to be implemented.
- Project management and reporting, schedule, project organization and responsibilities, manpower and cost projections, and required deliverables.
- QA objectives and protocols including tables summarizing field sampling and QA/QC analysis and objectives.

Note that this list of QAWP components is not all-inclusive and that additional elements may be added or altered depending on the specific requirements of the field investigation. It should also be recognized that although a detailed QAWP is quite important, it may be impractical in some instances. Emergency responses and accidental spills are prime examples of such instances where time might prohibit the development of site-specific QAWPs prior to field activities. In such cases, investigators would have to rely on general guidelines and personal judgment, and the sampling or response plans might simply be a strategy based on preliminary information and finalized on site. In any event, a plan of action should be developed, no matter how concise or informal, to aid investigators in maintaining a logical and consistent order to the implementation of their task.

7.5 Legal Implications

The data derived from sampling activities are often introduced as critical evidence during litigation of a hazardous waste site cleanup. Legal issues in which sampling data are important may include cleanup cost recovery, identification of pollution sources and responsible parties, and technical validation of remedial design methodologies. Because of the potential for involvement in legal actions, strict adherence to technical and administrative SOPs is essential during both the development and implementation of sampling activities.

Technically valid sampling begins with thorough planning and continues through the sample collection and analytical procedures. Administrative requirements involve thorough, accurate documentation of all sampling activities. Documentation requirements include maintenance of a chain of custody, as well as accurate records of field activities and analytical instructions. Failure to observe these procedures fully and consistently may result in data that are questionable, invalid and non-defensible in court, and the consequent loss of enforcement proceedings.

8.0 CALCULATIONS

Refer to the specific SOPs for any calculations which are associated with sampling techniques.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

Refer to the specific SOPs for the type and frequency of QA/QC samples to be analyzed, the acceptance criteria for the QA/QC samples, and any other QA/QC activities which are associated with sampling techniques.

10.0 DATA VALIDATION

Refer to the specific SOPs for data validation activities that are associated with sampling techniques.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures.

SOIL SAMPLING

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SUPERCEDES: SOP #2012; Revision 0.0; 11/16/94; U.S. EPA Contract 68-C4-0022.

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to describe the procedures for the collection of representative soil samples. Sampling depths are assumed to be those that can be reached without the use of a drill rig, direct-push, or other mechanized equipment (except for a back-hoe). Analysis of soil samples may determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be easily sampled using a spade, trowel, and scoop. Sampling at greater depths may be performed using a hand auger, continuous flight auger, a trier, a split-spoon, or, if required, a backhoe.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Chemical preservation of solids is not generally recommended. Samples should, however, be cooled and protected from sunlight to minimize any potential reaction. The amount of sample to be collected and proper sample container type are discussed in ERT/REAC SOP #2003 Rev. 0.0 08/11/94, *Sample Storage, Preservation and Handling*.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary potential problems associated with soil sampling - cross contamination of samples and improper sample collection. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

5.0 EQUIPMENT

Soil sampling equipment includes the following:

- Maps/plot plan
- Safety equipment, as specified in the site-specific Health and Safety Plan
- Survey equipment or global positioning system (GPS) to locate sampling points
- Tape measure
- Survey stakes or flags
- Camera and film
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Appropriate size sample containers
- Ziplock plastic bags
- Logbook
- Labels
- Chain of Custody records and custody seals
- Field data sheets and sample labels
- Cooler(s)
- Ice
- Vermiculite
- Decontamination supplies/equipment
- Canvas or plastic sheet
- Spade or shovel
- Spatula
- Scoop
- Plastic or stainless steel spoons
- Trowel(s)
- Continuous flight (screw) auger
- Bucket auger
- Post hole auger
- Extension rods
- T-handle
- Sampling trier
- Thin wall tube sampler
- Split spoons
- Vehimeyer soil sampler outfit
  - Tubes
  - Points
  - Drive head
  - Drop hammer
  - Puller jack and grip
- Backhoe

6.0 REAGENTS

Reagents are not used for the preservation of soil samples. Decontamination solutions are specified in ERT/REAC SOP #2006 Rev. 0.0 08/11/94, *Sampling Equipment Decontamination*, and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.

2. Obtain necessary sampling and monitoring equipment.

3. Decontaminate or pre-clean equipment, and ensure that it is in working order.

4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.

6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator (OSC) prior to soil sampling; and utility clearance should always be confirmed before beginning work.

7.2 Sample Collection

7.2.1 Surface Soil Samples

Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample.

This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member. A flat, pointed mason trowel to cut a block of the desired soil is helpful when undisturbed profiles are required. Tools plated with chrome or other materials should not be used. Plating is particularly common with garden implements such as potting trowels.

The following procedure is used to collect surface soil samples:

1. Carefully remove the top layer of soil or debris to the desired sample depth with a pre-cleaned spade.

2. Using a pre-cleaned, stainless steel scoop, plastic spoon, or trowel, remove and discard a thin layer of soil from the area which came in contact with the spade.

3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers

This system consists of an auger, or a thin-wall tube sampler, a series of extensions, and a "T" handle (Figure 1, Appendix A). The auger is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. If a core sample is to be collected, the auger tip is then replaced with a thin wall tube sampler. The system is then lowered down the borehole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Several types of augers are available; these include: bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery because they provide a large volume of sample in a short time. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

The following procedure is used for collecting soil samples with the auger:

1. Attach the auger bit to a drill rod extension, and attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first three to six inches of surface soil for an area approximately six inches in radius around the drilling location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the hole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

4. After reaching the desired depth, slowly and carefully remove the auger from the hole. When sampling directly from the auger, collect the sample after the auger is removed from the hole and proceed to Step 10.

5. Remove auger tip from the extension rods and replace with a pre-cleaned thin wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the soil. Do not scrape the borehole sides. Avoid hammering the rods as the vibrations may cause the boring walls to collapse.

7. Remove the tube sampler, and unscrew the drill rods.

8. Remove the cutting tip and the core from the device.

9. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.

10. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly.

    When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

11. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and follow steps 3 through 11, making sure to decontaminate the auger and tube sampler between samples.

12. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

7.2.3 Sampling with a Trier

The system consists of a trier, and a "T" handle. The auger is driven into the soil to be sampled and used to extract a core sample from the appropriate depth.

The following procedure is used to collect soil samples with a sampling trier:

1. Insert the trier (Figure 2, Appendix A) into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure that the slot is facing upward.

4. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted.

When split spoon sampling is performed to gain geologic information, all work should be performed in accordance with ASTM D1586-98, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils".

The following procedures are used for collecting soil samples with a split spoon:

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.

2. Place the sampler in a perpendicular position on the sample material.

3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.

4. Record in the site logbook or on field data sheets the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.

5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 1/2 inch diameters. A larger barrel may be necessary to obtain the required sample volume.

6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

7.2.5 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics are required. This is probably the most expensive sampling method because of the relatively high cost of backhoe operation.

The following procedures are used for collecting soil samples from test pits or trenches:

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.

2. Review the site specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.

3. Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.

4. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

5. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket.

6. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration

activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OHSA and corporate health and safety procedures, in addition to the procedures specified in the site specific Health & Safety Plan..

12.0 REFERENCES

Mason, B.J. 1983. Preparation of Soil Sampling Protocol: Technique and Strategies. EPA-600/4-83-020.

Barth, D.S. and B.J. Mason. 1984. Soil Sampling Quality Assurance User's Guide. EPA-600/4-84-043.

U.S. Environmental Protection Agency. 1984 Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. EPA-600/4-84-076.

de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. 1980. Samplers and Sampling Procedures for Hazardous Waste Streams. EPA-600/2-80-018.

ASTM D 1586-98, ASTM Committee on Standards, Philadelphia, PA.

APPENDIX A
Figures
SOP #2012
February 2000

FIGURE 1. Sampling Augers

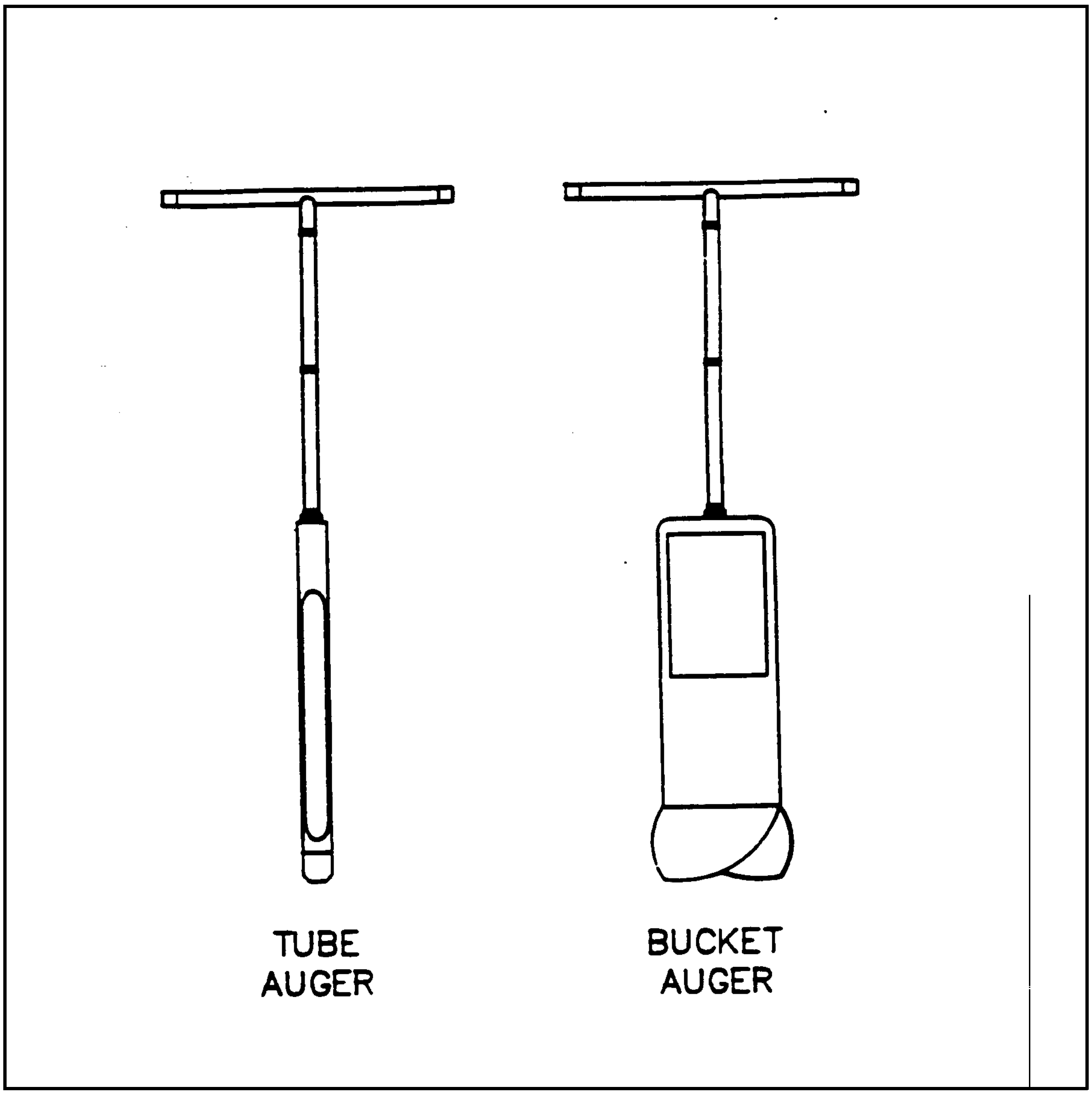
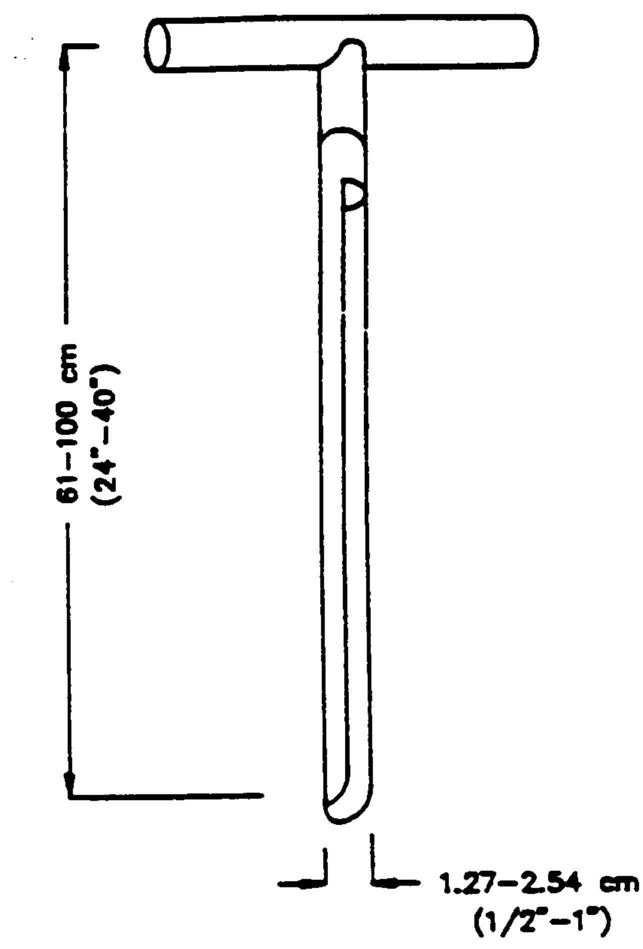


FIGURE 2. Sampling Trier



Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers

GROUND WATER FORUM ISSUE PAPER

Douglas Yeskis* and Bernard Zavala**

BACKGROUND

The Ground Water, Federal Facilities and Engineering Forums were established by professionals from the United States Environmental Protection Agency (USEPA) in the ten Regional Offices. The Forums are committed to the identification and resolution of scientific, technical, and engineering issues impacting the remediation of Superfund and RCRA sites. The Forums are supported by and advise OSWER's Technical Support Project, which has established Technical Support Centers in laboratories operated by the Office of Research and Development (ORD), Office of Radiation Programs, and the Environmental Response Team. The Centers work closely with the Forums providing state-of-the-science technical assistance to USEPA project managers.

This document provides sampling guidelines primarily for ground-water monitoring wells that have a screen or open interval with a length of ten feet or less and which can accept a sampling device. Procedures that minimize disturbance to the aquifer will yield the most representative ground-water samples. This document provides a summary of current and/or recommended ground-water sampling procedures. This document was developed by the Superfund/RCRA Ground Water Forum and incorporates comments from ORD, Regional Superfund hydrogeologists and others. These guidelines are applicable to the majority of sites, but are not intended to replace or supersede regional and/or project-specific sampling plans. These guidelines are intended to assist in developing sampling plans using the project-specific goals and objectives. However, unusual and/or site-specific circumstances may require approaches other than those specified in this document. In these instances, the appropriate Regional hydrologists/geologists should be contacted to establish alternative protocols.

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INTRODUCTION

The goal of ground-water sampling is to collect samples that are “representative” of in-situ ground-water conditions and to minimize changes in ground-water chemistry during sample collection and handling. Experience has shown that ground-water sample collection and handling procedures can be a source of variability in water-quality concentrations due to differences in sampling personnel, sampling procedures, and equipment (U.S. Environmental Protection Agency, 1995).

Several different ground-water sampling procedures can be used, which vary primarily through the criteria used to determine when a sample is representative of ground-water conditions. No single method or procedure is universally applicable to all types of ground-water-sampling programs; therefore, consideration should be given to a variety of factors when determining which method is best suited to site-specific conditions. These site-specific conditions include sampling objectives, equipment availability, site location, and physical constraints. This paper will discuss each of these conditions and how they may contribute to the decision in choosing the appropriate sampling methodology and equipment to be used during ground-water sampling.

This paper focuses on ground-water sampling procedures for monitoring wells only where separate, free-phase, Non-Aqueous Phase Liquids (NAPLs) are not present in the monitoring well. Residential and/or municipal-production wells where special sampling procedures and considerations need to be implemented are not discussed in this document. The recommendations made in this paper are based on findings presented in the current literature, and will be subject to revision as the understanding of ground-water-sampling procedures increases.

SAMPLING OBJECTIVES

The objective of a good sampling program should be the collection of a "representative" sample of the current ground-water conditions over a known or specified volume of aquifer. Ideally to meet this objective, sampling equipment, sampling method, monitoring well construction, monitoring well operation and maintenance, and sample handling procedures should not alter the chemistry of the sample. A sample that is obtained from a poorly constructed well, or using improper sampling equipment, or using poor sampling techniques, or which has been preserved improperly, can bias the sampling results. Unrepresentative samples can lead to misinterpretations of ground-water-quality data. Generally, the costs of obtaining representative ground-water samples are insignificant when compared to potential remedial responses that may be implemented based on erroneous data or when considering the overall monitoring program costs over the life of the program (Nielson, 1991).

The data quality objectives (DQOs) of the sampling program should be thoroughly developed, presented and understood by all parties involved. To develop the DQOs, the purpose of the sampling effort and data use(s) should be clearly defined. The sampling guidelines presented here can be used for a variety of monitoring programs, these include site assessment, contaminant detection, site characterization, remediation, corrective action and compliance monitoring.

For example DQOs for a site characterization sampling effort might vary from those of a remediation monitoring sampling effort. This difference could be in how much of the screen interval should be sampled. A site characterization objective may be to collect a sample that represents a composite of the entire (or as close as is possible) screened interval of the monitoring well. On the other hand, the monitoring objective of a remediation monitoring program may be to obtain a sample that represents a specific portion of the screened interval.

Additionally, the site characterization may require analyses for a broad suite of contaminants, whereas, the remediation monitoring program may require fewer contaminants to be sampled. These differences may dictate the type of sampling equipment used, the type of information collected, and the sampling protocol.

In order to develop applicable DQOs, a site conceptual model should be developed. The site conceptual model should be a dynamic model which is constantly revised as new information is collected and processed. The conceptual model, as it applies to the DQOs, should focus on contaminant fate and transport processes, such as contaminant pathways, how the geologic materials control the contaminant pathways (depositional environments, geologic structure, lithology, etc.), types of contaminants present (i.e., hydrophobic versus hydrophilic), and the processes that influence concentrations of the contaminants present such as dilution, biodegradation, and dispersion. The detail of the conceptual model will depend greatly on the availability of information, such as the number of borings and monitoring wells and the amount of existing analytical data. Clearly, a site that is being investigated for the first time will have a much simpler conceptual model compared to a site that has had a Remedial Investigation, Feasibility Study, and Remedial Design, (or, within the RCRA Program, a RCRA Facility Assessment, a RCRA Facility Investigation, and a Corrective Measures Study), and is currently in remediation/corrective action monitoring. Specific parameters that a conceptual model should describe that may impact the design of a ground-water-sampling program include:

a) The thickness, lateral extent, vertical and horizontal flow direction, and hydraulic conductivity contrasts of the geologic materials controlling contaminant transport from the site (thick units versus thin beds versus fractures, etc.)

b) The types of contaminants to be sampled (volatile organic compounds, semi-volatile organic compounds, metals, etc.) and factors that could bias sampling results (turbidity for metals, co-solvation effects on PCBs, etc.)

c) Lateral and vertical distribution of contamination (contaminants distributed throughout an entire unit being monitored versus localized distribution controlled by small scale features, etc.)

Vertical aquifer characterization is strongly recommended prior to the completion of a ground-water monitoring well installation program. A detailed vertical aquifer characterization program should include field characterization of hydraulic conductivities, determination of vertical and horizontal flow directions, assessment of lithologic and geologic variations, and determination of vertical and horizontal contaminant distributions. The successful aquifer characterization program provides detailed information to guide the technical and cost-effective placement, vertically and areally, of monitoring wells.

INFORMATION NEEDED PRIOR TO SAMPLING

To ensure appropriate methodology and expedient collection of water-quality samples, information is needed before a sample is collected. Some information should be obtained prior to the start of field activities such as well condition, construction, water-level information, contaminant types and concentrations, and direction(s) of ground-water flow. Field measurements, such as depth to water and total well depth will be needed prior to purging. Before commencement of all field activities, the field health and safety plan should be consulted under the direction of the site health and safety officer.

BACKGROUND DATA

Well construction and maintenance information are needed to better plan the sampling program, optimize personnel, and obtain more representative samples. Prior to field activities, personnel should have specific information including well casing diameter, borehole diameter, casing material, lock number and keys, physical access to wells, and length of and depth to well screen. The diameter of each well casing is used to select the correct equipment and technique for purging and sampling the well. A site map with possible physical barriers and description of access is necessary to allow for the selection of proper equipment based on several factors, such as portability, ease of repair, power sources, containment of purge water, and well accessibility. The length and depth of each well screen and depth to water is important when placing a sampling device's intake at the proper depth for purging and sampling and for choosing a sampling device. Well development information is needed to ensure that purging and sampling rates will not exceed well development extraction rates. Previous sampling information should be provided and evaluated to determine the nature and concentrations of expected contaminants. This will be useful in determining the appropriate sampling method and quality assurance/quality control (QA/QC) samples (for example, field duplicates, equipment blanks, trip blanks). Attachment 1 is an example of a sampling checklist for field personnel. This information should be kept in the field for easy access during sampling activities.

When evaluating previous sampling information, consideration should be given to the amount of time that has expired between the last sampling effort and the planned sampling effort. If this time exceeds one year, the need for redevelopment of the monitoring wells should be evaluated. The necessity of redevelopment can be evaluated by measuring constructed depth compared to the measured depth. If the depth measurement indicates siltation of the monitoring well screen, or evidence exists that the well screen is clogged, the well should be redeveloped prior to sampling. The assessment of the condition of the monitoring wells should be completed several weeks prior to sampling activities in order to allow the proper recovery of the developed wells. This is especially important in wells where prior sampling has indicated high turbidity. The time for a well to re-stabilize after development is dependent on site-specific geology and should be specified in the site sampling plan. The development method, if necessary, should be consistent with the sampling objectives, best technical criteria and USEPA guidelines (Aller et al., 1991; Izraeli et al., 1992; Lapham et al., 1997).

REFERENCE POINT

Each well should be clearly marked with a well identifier on the outside and inside of the well casing. Additionally, each well should have a permanent, easily identified reference point from which all depth measurements are taken. The reference point (the top of the inner casing, outer casing, or security/protective casing) should remain constant through all measurements, should be clearly marked on the casing and its description recorded. Whenever possible, the inner casing is recommended as a reference point, because of the general instability of outer casings due to frost heaving, vehicular damage, and other phenomena which could cause movement of casings. The elevation of this reference point should be known and clearly marked at the well site (Nielson, 1991).

This reference point should also have a known latitude and longitude that are consistent with the Regional and National Minimum Data Elements requirements. The elevation of the reference point should be surveyed relative to Mean Sea Level (MSL) using the NAVD 88 datum.

TOTAL WELL DEPTH

The depth of the well is required to calculate the volume of standing water in the well and to document the amount of siltation that may have occurred. Moreover, measuring the depth to the bottom of a well provides checks for casing integrity and for siltation of the well screen. Corrosion can cause leaking or collapse of the well casing, which could lead to erroneous or misleading water-level measurements. Corrosion, silting, and biofouling can clog well screens and result in a sluggish response or no response to water-level changes, as well as changes in ground-water chemistry. Well redevelopment or replacement may be needed to ensure accurate collection of a representative water-quality sample.

Total well depths should be measured and properly recorded to the nearest one-tenth of a foot using a steel tape with a weight attached. The steel tape should be decontaminated before use in another well according to the site specific protocols. A concern is that when the steel tape and weight hit the bottom of the well, sediment present on the bottom of a well may be stirred up, thus increasing turbidity which will affect the sampling results. The frequency of total well depth measurements varies, with no consensus for all hydrogeologic conditions. The United States Geological Survey (USGS) recommends a minimum of once a year (Lapham et al., 1997). USEPA also recommended one measurement per year (Barcelona et al., 1985) but later recommended a total well depth be taken every time a water-quality is collected or a water-level reading taken (Aller et al., 1991). Therefore, when possible, the total depth measurements should be taken following the completion of sampling (Puls and Barcelona, 1996). When total-well-depth measurements are needed prior to sampling, as much time as possible should be allowed prior to sampling, such as a minimum of 24 hours. The weight of electric tapes are generally too light to determine accurate total well depth. If the total well depth is greater than 200 feet, stretching of the tape must be taken into consideration.

DEPTH TO WATER

All water levels should be measured from the reference point by the use of a weighted steel tape and chalk or an electric tape (a detailed discussion of the pros and cons of the different water level devices is provided in Thornhill, 1989). The steel tape is a more accurate method to take water levels, and is recommended where shallow flow gradients (less than 0.05 foot/feet or 0.015 meter/meters) or deep wells are encountered. However, in those cases where large flow gradients or large fluctuations in water levels are expected, a calibrated electric tape is acceptable. The water level is calculated using the well's reference point minus the measured depth to water. At depths approximately greater than 200 feet, the water-level-measuring device should be chosen carefully, as some devices may have measurable stretching.

The depth-to-water measurement must be made in all wells to be sampled prior to activities in any single well which may change the water level, such as bailing, pumping, and hydraulic testing. All readings are to be recorded to the nearest one-hundredth of a foot.

The time and date of the measurement, point of reference, measurement method, depth-to-water level measurement, and any calculations should be properly recorded. In addition, any known, outside influences (such as tidal cycles, nearby pumping effects, major barometric changes) that may affect water levels should be noted.

GROUND-WATER SAMPLING METHODS

The ground-water sampling methods to be employed should be dependent on site-specific conditions and requirements, such as data-quality objectives and well accessibility. Ground-water sampling methods vary based on the type of device used, the position of the sampler intake, the purge criteria used, and the composition of the ground water to be sampled (e.g., turbid, containing high volatile organics, etc.). All sampling methods and equipment should be clearly documented, including purge criteria, field readings, etc. Examples of appropriate documentation are provided in Attachment 2 of this document and Appendix E of the U.S. Environmental Protection Agency, 1995 document.

The water in the screen and filter pack is generally in a constant state of natural flux as ground water passes in and out of the well. However, water above the screened section remains relatively isolated and become stagnant. Stagnant water is subject to physio-chemical changes and may contain foreign material, which can be introduced from the surface or during well construction, resulting in non-representative sample data. To safeguard against collecting a sample biased by stagnant water, specific well-purging guidelines and techniques should be followed.

A non-representative sample also can result from excessive pumping of the monitoring well. Stratification of the contaminant concentrations in the aquifer may occur, or heavier-than-water compounds may sink to the lower portions of the aquifer. Excessive pumping can dilute or increase the contaminant concentrations from what is representative of the sampling point.

PURGING AND SAMPLING DEVICES

The device used to purge and sample a well depends on the inner casing diameter, depth to water, volume of water in the well, accessibility of the well, and types of contaminants to be sampled. The types of equipment available for ground-water sampling include hand-operated or motor-driven suction pumps, peristaltic pumps, positive displacement pumps, submersible pumps, various in-situ devices and bailers made of various materials, such as PVC, stainless steel and Teflon®. Some of these devices may cause volatilization and produce high pressure differentials, which could result in variability in the results of pH, dissolved oxygen concentrations, oxidation-reduction potential, specific electrical conductance, and concentrations of metals, volatile organics and dissolved gases. Therefore, the device chosen for well purging and sampling should be evaluated for the possible effects it may have on the chemical and physical analyses. In addition, the types of contaminants, detection levels, and levels of concern as described by the site DQOs should be consulted prior to the selection of a sampling device. The same device used for purging the monitoring well should be used for sampling to minimize agitation of the water column (which can increase turbidity, increase volatilization, and increase oxygen in the water).

In general, the device used for purging and sampling should not change geochemical and physical parameters and/or should not increase turbidity. For this reason, low-flow submersible or positive-displacement pumps that can control flow rates are recommended for purging wells. Dedicated sampling systems are greatly preferred since they avoid the need for decontamination of equipment and minimize turbulence in the well. If a sampling pump is used, the pump should be lowered into the well as slowly as possible and allowed to sit as long as possible, before pumping commences. This will minimize turbidity and volatilization within the well.

Sampling devices (bladders, pumps, bailers, and tubing) should be constructed of stainless steel, Teflon®, glass, and other inert materials to reduce the chance of these materials altering the ground water in areas where concentrations of the site contaminants are expected to be near detection limits. The sample tubing thickness should be maximized and the tubing length should be minimized so that the loss of contaminants through the tubing walls may be reduced and the rate of stabilization of ground-water parameters is maximized. The tendency of organics to sorb into and out of many materials makes the appropriate selection of sample tubing materials critical for these trace analyses (Pohlmann and Alduino, 1992; Parker and Ranney, 1998). Existing Superfund and RCRA guidance suggest appropriate compatible materials (U.S. Environmental Protection Agency, 1992). Special material considerations are important when sampling for non-routine analyses, such as age-dating and biological constituents.

Preferably, wells should be purged and sampled using a positive-displacement pump or a low-flow submersible pump with variable controlled flow rates and constructed of chemically inert materials. If a pump cannot be used because the recovery rate is so slow (less than 0.03 to 0.05 gallons per minute or 100 to 200 milliliters per minute) and the volume of the water to be removed is minimal (less than 5 feet (1.6 meters) of water), then a bailer with a double check valve and bottom-emptying device with a control-flow check valve may be used to obtain the samples. Otherwise, a bailer should not be used when sampling for volatile organics because of the potential bias introduced during sampling (Pohlmann, et al., 1990; Yeskis, et al., 1988; Tai, et al., 1991). A peristaltic pump also may be used under these conditions, unless the bias by a negative pressure may impact the contaminant concentrations of concern (generally at depths greater than 15 to 20 feet (4.5 to 6 meters) of lift). Bailers should also be avoided when sampling for metals due to increased turbidity that occurs during the deployment of the bailer, which may bias inorganic and strongly hydrophobic parameters. Dedicated sampling pumps are recommended for metals sampling because the pumps avoid the generation of turbidity from frequent sampler deployment (Puls et al., 1992). A number of alternate sampling devices are becoming available, including passive diffusion samplers (Vroblesky and Hyde, 1997; Vroblesky, 2001a and b) and other in-situ sampling devices. These devices may be particularly useful to sampling low-permeability geologic materials, assuming the device is made of materials compatible with the analytical parameters, meet DQOs, and have been properly evaluated. However, the site investigator should ensure the diffusion membrane materials are selected for the contaminants of concern (COCs) present at the site. Comparison tests with an approved sampling method and diffusion samplers should be completed to confirm that the method is suitable for the site.

POSITION OF SAMPLE INTAKE

Essentially there are two positions for placement of the sample pump intake, within the screen and above the screen. Each of the positions offers advantages and disadvantages with respect to the portion of the well screen sampled, data reproducibility and potential purge volumes.

When the sampling pump intake is set above the well screen, the pump generally is set just below the water level in the well. The sampling pump then is pumped until a purge criterion is reached (commonly either stabilization of purge parameters or a set number of well volumes). If the distance between the water level and the top of the screen is long, there is concern that the water will be altered geochemically as it flows along the riser pipe, as water flows between the well screen and the sampling pump intake. This is especially a concern if the riser pipe is made of similar material as the COC (such as a stainless steel riser with nickel as a COC, or PVC with organics as a COC). Keely and Boateng (1987) suggested that to minimize this potential influence, the sample pump be lowered gradually while purging, so that at the time of the sampling the pump intake is just above the screen. This would minimize contact time between the ground water and the well construction materials while sampling, as well as ensure the evacuation of the stagnant water above the screen.

With the final location of the sampling pump intake just above the well screen, the sample results may be more reproducible than those collected by positioning the pump intake within the well screen. Results may be more reproducible because the sampler can ensure that the ground water is moving into the well with the same portions of the aquifer being sampled each time assuming the same pump rate. If the pump is placed into different portions of the screen each time, different portions of the aquifer may be sampled. Of course, this can be avoided by the use of dedicated, permanently installed equipment. Additionally, the placement of the pump at the same vertical position within the screen can be ensured by the use of calibrated sampling pump hose, sounding with a weighted tape, or using a pre-measured hose.

The placement of the pump above the screen does not guarantee the water-quality sample represents the entire well screen length. Any bias in the pump placement will be consistently towards the top of the well screen and/or to the zone of highest hydraulic conductivity. Another possible disadvantage, or advantage, depending on the DQOs, of the placement of the pump above the well screen is that the sample may represent a composite of water quality over the well screen. This may result in dilution of a portion of the screen that is in a contaminated portion of an aquifer with another portion that is in an uncontaminated portion of the aquifer. However, shorter well screens would minimize this concern.

When the pump intake is positioned within the well screen, its location is recommended to be opposite the most contaminated zone in the well screen interval. This method is known as the low-flow, low-stress, micropurge, millipurge, or minimal drawdown method. The well is then purged with a minimal drawdown (usually 0.33 feet (0.1 meters) based on Puls and Barcelona, 1996) until selected water-quality-indicator parameters have stabilized. Use of this method may result in the vertical portion of the sampled aquifer being smaller than the well screen length. This method is applicable primarily for short well-screen lengths (less than 5 feet (1.6 meters)) to better characterize the vertical distribution of contaminants (Puls and Barcelona, 1996). This method should not be used with well-screen lengths greater than 10 feet (3 meters). By using this method, the volume of purge water can be reduced, sometimes significantly, over other purging methods.

However, two potential disadvantages of this method exist. The first potential disadvantage may involve the lower reproducibility of the sampling results. The position of the sampling pump intake may vary between sampling rounds (unless adequate precautions are taken to lower the pump into the exact position in previous sampling rounds, or a dedicated system is used), which can result in potentially different zones within the aquifer being sampled. This potential problem can be overcome by using dedicated sampling pumps and the problem may be minimized by the use of short well screens. The second potential disadvantage, or advantage, depending on the DQOs, may be that the sample which is collected may be taken from a small portion of the aquifer volume.

PURGE CRITERIA

"Low-Stress Approach"

The first method for purging a well, known as the low-stress approach, requires the use of a variable-speed, low-flow sampling pump. This method offers the advantage that the amount of water to be containerized, treated, or stored will be minimized. The low-stress method is based on the assumption that pumping at a low rate within the screened zone will not draw stagnant water down, as long as drawdown is minimized during pumping. Drawdown should not exceed 0.33 feet (0.1 meters) (Puls and Barcelona, 1996). The pump is turned on at a low flow rate approximating the estimated recovery rate (based on the drawdown within the monitoring well during sampling). This method requires the location of the pump intake to be within the saturated-screened interval during purging and sampling. The water-quality-indicator parameters (purge parameters), pH, specific electrical conductance, dissolved oxygen concentration, oxidation-reduction potential, temperature and turbidity, are monitored at specific intervals. The specific intervals will depend on the volume within the tubing (include pump and flow-through cell volumes), pump rate and drawdown; commonly every three to five minutes. These parameters should be recorded after a minimum of one tubing volume (include pump and flow-through-cell volumes) has been purged from the well. These water-quality-indicator parameters should be collected by a method or device which prevents air from contacting the sample prior to the reading, such as a flow-through cell (Barcelona et al., 1985; Garske and Schock, 1986; Wilde et al., 1998). Once three successive readings of the water-quality-indicator parameters provided in Table 1 have stabilized, the sampling may begin. The water-quality-indicator parameters that are recommended include pH and temperature, but these are generally insensitive to indicate completion of purging since they tend to stabilize rapidly (Puls and Barcelona, 1996). Oxidation-reduction potential may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions, and for some fate and transport issues. When possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs). For final dissolved oxygen measurements, if the readings are less than 1 milligram per liter, they should be collected with the spectrophotometric method (Wilde et al., 1998, Wilkin et al., 2001), colorimetric or Winkler titration (Wilkin et al., 2001). All of these water-quality-indicator parameters should be evaluated against the specifications of the accuracy and resolution of the instruments used.

During purging, water-level measurements must be taken regularly at 30-second to five-minute intervals (depending on the hydraulic conductivity of the aquifer, diameter of the well, and pumping rate) to document the amount of drawdown during purging. The water-level measurements will allow the sampler to control pumping rates to minimize drawdown in the well.

"Well-Volume Approach"

The second method for purging wells is based on proper purging of the stagnant water above the screened interval and the stabilization of water-quality-indicator parameters prior to sampling. Several considerations in this method need to be evaluated before purging. For monitoring wells where the water level is above the screens, the pump should be set near the top of the water column, and slowly lowered during the purging process. For water columns within the well screen, the pump should be set at a sufficient depth below the water level where drawdown during pumping does not allow air to enter the pump. The pump should not be allowed to touch or draw sediments from the bottom of the well, especially when sampling for parameters that may be impacted by turbidity. The well-purging rate should not be great enough to produce excessive turbulence in the well, commonly no greater than one gallon per minute (3.8 liters per minute) in a 2-inch well. The pump rate during sampling should produce a smooth, constant (laminar) flow rate, and should not produce turbulence during the filling of bottles. As a result, the expected flow rate for most wells will be less than one gallon per minute (3.8 liter per minute), with expected flow rates of about one-quarter gallon per minute (500 milliliter per minute).

The stabilization criteria for a "well-volume approach" may be based on the stabilization of water-quality-indicator parameters or on a pre-determined well volume. Various research indicates that purging criteria based on water-quality-indicator parameter stabilization may not always correlate to stabilization of other parameters, such as volatile organic compounds (Gibs and Imbrigiotta, 1990; Puls et al., 1990). A more technically rigorous sampling approach that would yield more consistent results over time would be a time-sequential sampling program at regular well-volume intervals while measuring water-quality-indicator parameters. However, the cost would be prohibitive for most sites. For comparison of water-quality results, by sampling under the same conditions (same purge volume and rate, same equipment, same wells, etc.) temporal evaluations of trends may be considered.

The stabilization requirements of the water-quality-indicator parameters are consistent with those described above for the low-stress approach. The parameters should be recorded approximately every well volume; when three successive readings have reached stabilization, the sample(s) are taken (Barcelona et al., 1985). If a ground-water monitoring well has been sufficiently sampled and characterized (at least several rounds of water-quality samples obtained, including the field parameters, during several seasonal variations), and if water-quality-indicator parameters are no longer needed as a part of site characterization and/or monitoring, then samples could be obtained based on a specific number of well volumes at the previous pumping rates.

LOW-PERMEABILITY FORMATIONS

Different procedures must be followed in the case of slow-recovery wells installed in low hydraulic conductivity aquifers. The following procedures are not optimum, but may be used to obtain a ground-water sample under less than ideal conditions. One suggested procedure is to remove the stagnant water in the casing to just above the top of the screened interval, in a well screened below the water table, to prevent the exposure of the gravel pack or formation to atmospheric conditions (McAlary and Barker, 1987). At no point should the pump be lowered into the screened interval. The pumping rate should be as low as possible for purging to minimize the drawdown in the well. However, if a well has an open interval across the water table in a low permeability zone, there may be no way to avoid pumping and/or bailing a well dry (especially in those cases with four feet of water or less in the well and at a depth to water greater than 20 to 25 feet (which is the practical limit of a peristaltic pump)). In these cases, the well may be purged dry. The sample should be taken no sooner than two hours after purging and after a sufficient volume for a water-quality sample, or sufficient recovery (commonly 90%) is present (Herzog et al., 1988). In these cases, a bailer with a double check valve with a flow-control, bottom-emptying device may be used, since many sampling pumps may have tubing capacities greater than the volume present within the well. If the depth of well and water column are shallow enough, consideration of a very low-flow device, such as a peristaltic pump, should be considered, especially if constituents are present that are not sensitive to negative pressures that may be created with the use of the peristaltic pump. If such constituents are present and sampled with a peristaltic pump, a negative bias may be introduced into the sampling results. To minimize the bias, thick-walled, non-porous tubing should be used, except for a small section in the pump heads, which require a greater degree of flexibility. As stated earlier in this paper, the DQOs for the sampling should be consulted to consider the potential impact of the sampling device on the potential bias versus the desired detection levels.

Another method to be considered for low-permeability conditions is the use of alternative sampling methods, such as passive diffusion samplers and other in-situ samplers. As more sites are characterized with these alternative sampling methods and devices, the potential bias, if any, can be evaluated with regard to the sampling DQOs. Regional hydrologists/geologists and Regional quality-assurance specialists should be consulted on the applicability of these methods for the site-specific conditions.

DECISION PROCESS FOR DETERMINING APPLICABLE SAMPLING METHODOLOGY

Once the project team has determined the sampling objectives and DQOs, reviewed the existing data, and determined the possible sampling devices that can be used, the team must decide the appropriate sampling methodology to be used. Table 2 provides a summary of considerations and rationale to be used in establishing the proper ground-water-sampling program using site-specific conditions and objectives.

POTENTIAL PROBLEMS

The primary objective is to obtain a sample representative of the ground water moving naturally (including both dissolved and particulate species) through the subsurface. A ground-water sample can be compromised by field personnel in two primary ways: taking an unrepresentative sample and handling the (representative) sample incorrectly. There are numerous ways of introducing foreign contaminants into a sample. These must be avoided by following strict sampling protocols and transportation procedures, and utilizing trained personnel. Common problems with sampling include the use of inappropriate sample containers and field composites, and the filtration of turbid samples.

SAMPLE CONTAINERS

Field samples must be transferred from the sampling equipment to the container that has been specifically prepared for that given parameter. Samples must not be composited in a common container in the field and then split in the lab. The USEPA Regional policy on sample containers should be consulted to determine the appropriate containers for the specified analysis.

FIELD FILTRATION OF TURBID SAMPLES

The USEPA recognizes that in some hydrogeologic environments, even with proper well design, installation, and development, in combination with the low-flow purging and sampling techniques, sample turbidity cannot be reduced to ambient levels. The well construction, development, and sampling information should be reviewed by the Regional geologists or hydrologists to see if the source of the turbidity problems can be resolved or if alternative sampling methodologies should be employed. If the water sample is excessively turbid, the collection of both filtered and unfiltered samples, in combination with turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pumping rate, and drawdown data is recommended. The filter size used to determine TSS and TDS should be the same as used in the field filtration. An in-line filter should be used to minimize contact with air to avoid precipitation of metals. The typical filter media size used is 0.45 µm because this is commonly accepted as the demarcation between dissolved and non-dissolved species. Other filter sizes may be appropriate but their use should be determined based on site-specific criteria (examples include grain-size distribution, ground-water-flow velocities, mineralogy) and project DQOs. Filter sizes up to 10.0 µm may be warranted because larger size filters may allow particulates that are mobile in ground water to pass through (Puls and Powell, 1992). The changing of filter media size may limit the comparability of the data obtained with other data sets and may affect their use in some geochemical models. Filter media size used on previous data sets from a site, region or aquifer and the DQOs should be taken into consideration. The filter media used during the ground-water sampling program should be collected in a suitable container and archived because potential analysis of the media may be helpful for the determination of particulate size, mineralogy, etc.

The first 500 to 1000 milliliters of a ground-water sample (depending on sample turbidity) taken through the in-line filter will not be collected for a sample in order to ensure that the filter media has equilibrated to the sample (manufacturer's recommendations also should be consulted). Because bailers have been shown to increase turbidity while purging and sampling, bailers should be avoided when sampling for trace element, metal, PCB, and pesticide constituents. If portable sampling pumps are used, the pumps should be gently lowered to the sampling depth desired, carefully avoiding lowering it to the bottom of the well, and allowed to sit in order to allow any particles mobilized by pump placement to settle. Dedicated sampling equipment installed in the well prior to the commencement of the sampling activities is one of the recommended methods to reduce turbidity artifacts (Puls and Powell, 1992; Kearl et al., 1992; Puls et al., 1992; Puls and Barcelona, 1996).

SAMPLER DECONTAMINATION

The specific decontamination protocol for sampling devices is dependent on site-specific conditions, types of equipment used and the types of contaminants encountered. Once removed from the well, non-dedicated sampling equipment should be decontaminated to help ensure that there will be no cross-contamination between wells. Disposable items such as rope and low-grade tubing should be properly disposed between wells. Cleaning thoroughly that portion of the equipment that is going to come into contact with well water is especially important. In addition, a clean plastic sheet should be placed adjacent to or around the well to prevent surface soils from coming in contact with the purging and sampling equipment. The effects of cross-contamination can be minimized by sampling the least contaminated well first and progressing to the more contaminated ones. Equipment blanks should be collected on a regular basis from non-dedicated equipment, the frequency depending on the sampling plan and regional protocols, to document the effectiveness of the decontamination procedures.

The preferred method is to use dedicated sampling equipment whenever possible. Dedicated equipment should still be cleaned on a regular basis to reduce biofouling, and to minimize adsorption effects. Dedicated equipment should have equipment blanks taken after every cleaning.

POST-SAMPLING ACTIVITIES

Specific activities should be completed at monitoring wells at regular intervals to ensure the acquisition of representative ground-water samples. Activities include hydraulic conductivity testing to determine if a monitoring well needs redeveloping and/or replacing. Another activity that needs to be completed is regular surveying of well measuring points impacted by frost heaving and site activities. The schedules of these activities are to be determined on a site-by-site basis in consultation with regional geologists or hydrologists, but at a minimum, should be every five years.

CONCLUSION

This document provides a brief summary of the state-of-the-science to be used for Superfund and RCRA ground-water studies. As additional research is completed, additional sampling experience with other sampling devices and methods and/or additional contaminants are identified, this paper may be revised to include the new information/concerns. Clearly there is no one sampling method that is applicable for all sampling objectives. As new methods and/or equipment are developed, additional standard operating procedures (SOPs) should be developed and attached to this document. These SOPs for ground-water sampling should include, at a minimum: introduction, scope and application, equipment, purging and sampling procedures, field quality control, decontamination procedures and references. Example SOP's for the low-stress/minimal-drawdown and well-volume sampling procedures have been included as Attachments 3 and 4. These example SOPs are to be considered a pattern or starting point for site-specific ground-water-sampling plans. A more detailed discussion of sampling procedures, devices, techniques, etc. is provided in various publications by the USEPA (Barcelona et al., 1985; U.S. Environmental Protection Agency, 1993) and the U.S. Geological Survey (Wilde et al., 1998).

REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson and J.E. Denne, 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells; U.S. Environmental Protection Agency, EPA/600/4-89/034, 221 pp.

Barcelona, M.J., J.P. Gibb, J.A. Hellfrich, and E.E. Garske, 1985, Practical Guide for Ground-Water Sampling; U.S. Environmental Protection Agency, EPA/600/2-85/104, 169 pp.

Garske, E.E., and M.R. Schock, 1986, An Inexpensive Flow-Through Cell and Measurement System for Monitoring Selected Chemical Parameters in Ground Water; Ground Water Monitoring Review, Vol. 6, No. 3, pp. 79-84.

Gibs, J. and T.E. Imbrigiotta, 1990, Well-Purging Criteria for Sampling Purgeable Organic Compounds; Ground Water, Vol. 28, No. 1, pp.68-78.

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, Vol. 8, No. 4, pp. 93-99.

Izraeli, R., D. Yeskis, M. Collins, K. Davies and B. Zavala, 1992, GROUND WATER ISSUE PAPER: Monitoring Well Development Guidelines for Superfund Project Managers; U.S. Environmental Protection Agency, 4 pp.

Kearl, P.M., N.E. Korte, and T.A. Cronk, 1992, Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloid Borescope; Ground Water Monitoring Review, Vol. 12, No. 2, pp. 155-161.

Keely, J.F. and K. Boateng, 1987, Monitoring well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations; Ground Water, Vol. 25, No. 4, pp. 427-439.

Lapham, W.W., F.D. Wilde and M.T. Koterba, 1997, Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells, and Supporting Documentation; U.S. Geological Survey Water-Resources Investigations Report 96-4233, 110 pp.

McAlary, T.A. and J.F. Barker, 1987, Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials; Ground Water Monitoring Review, Vol. 7, No. 4, pp. 63-68.

Nielson, D.M., 1991, Practical Handbook of Ground-Water Monitoring; Lewis Publishers, 717 pp.

Parker, L.V. and T.A. Ranney, 1998, Sampling Trace-Level Organic Solutes with Polymeric Tubing: Part 2, Dynamic Studies; Ground Water Monitoring and Remediation, Vol. 18, No. 1, pp. 148-155.

Pohlmann, K.F., R.P. Blegen, and J.W. Hess, 1990, Field Comparison of Ground-Water Sampling Devices for Hazardous Waste Sites: An Evaluation using Volatile Organic Compounds; U.S. Environmental Protection Agency, EPA/600/4-90/028, 102 pp.

Pohlmann, K.F. and A.J. Alduino, 1992, GROUND-WATER ISSUE PAPER: Potential Sources of Error in Ground-Water Sampling at Hazardous Waste Sites; U.S. Environmental Protection Agency, EPA/540/S-92/019.

Puls, R.W., J.H. Eychaner, and R.M. Powell, 1990, ENVIRONMENTAL RESEARCH BRIEF: Colloidal-Facilitated Transport of Inorganic Contaminants in Ground Water: Part I. Sampling Considerations; U.S. Environmental Protection Agency, EPA/600/M-90/023, 12 pp.

Puls, R.W. and R.M. Powell, 1992, Acquisition of Representative Ground Water Quality Samples for Metals; Ground Water Monitoring Review, Vol. 12, No. 3, pp. 167-176.

Puls, R.W., D.A. Clark, B. Bledsoe, R.M. Powell and C.J. Paul, 1992, Metals in Ground Water: Sampling Artifacts and Reproducibility; Hazardous Waste and Hazardous Materials, Vol. 9, No. 2, pp. 149-162.

Puls, R.W. and M.J. Barcelona, 1996, GROUND-WATER ISSUE PAPER: Low-Flow (Minimal Draw-down) Ground-Water Sampling Procedures; U.S. Environmental Protection Agency, EPA/540/S-95/504, 12 pp.

Tai, D.Y., K.S. Turner, and L.A. Garcia, 1991, The Use of a Standpipe to Evaluate Ground Water Samples; Ground Water Monitoring Review, Vol. 11, No. 1, pp. 125-132.

Thornhill, J.T., 1989, GROUND-WATER ISSUE PAPER: Accuracy of Depth to Water Measurements; U.S. Environmental Protection Agency, EPA/540/4-89/002, 3 pp.

U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; EPA/530-R-93-001.

U.S. Environmental Protection Agency, 1993, Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide: Volume I: Solids and Ground Water Appendices A and B; EPA/625/R-93/003a.

U.S. Environmental Protection Agency, 1995, Ground Water Sampling - A Workshop Summary, Dallas, Texas, November 30-December 2, 1993; EPA/600/R-94/205, 146 pp.

Vroblesky, D.A., 2001a, User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells, Part 1: Deployment, Recovery, Data Interpretation, and Quality Control and Assurance; U.S. Geological Survey Water-Resources Investigations Report 01-4060,
18 pp.

Vroblesky, D.A. ed., 2001b, User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells, Part 2: Field Tests; U.S. Geological Survey Water-Resources Investigations Report 01-4061, variously paginated.

Vroblesky, D.A. and Hyde, W.T., 1997, Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water; Ground Water Monitoring and Remediation, Vol. 17, No. 3, pp. 177-184.

Wilde, F.D., D.B. Radtke, J.Gibs and R.T. Iwatsubo, eds., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, variously paginated.

Wilkin, R.T., M.S. McNeil, C.J. Adair and J.T. Wilson, 2001, Field Measurement of Dissolved Oxygen: A Comparison of Methods, Ground Water Monitoring and Remediation, Vol. 21, No. 4, pp. 124-132.

Yeskis, D., K. Chiu, S. Meyers, J. Weiss, and T. Bloom, 1988, A Field Study of Various Sampling Devices and Their Effects on Volatile Organic Contaminants; Proceedings of the Second National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, National Water Well Association, May 1988.

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TABLES:

Stablization Criteria with References for Water-Quality-Indicator Parameters

and

Applicability of Different Approaches for Purging and Sample Monitoring Wells

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TABLE 1: Stabilization Criteria with References for Water-Quality-Indicator Parameters

Parameter	Stabilization Criteria	Reference
pH	+/- 0.1	Puls and Barcelona, 1996; Wilde et al., 1998
specific electrical conductance (SEC)	+/- 3%	Puls and Barcelona, 1996
oxidation-reduction potential (ORP)	+/- 10 millivolts	Puls and Barcelona, 1996
turbidity	+/- 10% (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996; Wilde et al., 1998
dissolved oxygen (DO)	+/- 0.3 milligrams per liter	Wilde et al., 1998

TABLE 2: Applicability of Different Approaches for Purging and Sampling Monitoring Wells

	Low-Stress Approach	Well-Volume Approach	**Others** (such as passive diffusion samplers, in-situ samplers, and other non-traditional ground-water sampling pumps)
Applicable Geologic Materials[1]	Materials with moderate to high hydraulic conductivities. May be applicable to some low hydraulic conductivities, if can meet minimal drawdown criteria.	Materials with low to high hydraulic conductivities	Materials with very low to high hydraulic conductivities
Aquifer/Plume Characterization Data Needs prior to Choosing Sampling Method[2]	High definition of vertical hydraulic conductivity distribution and vertical contaminant distribution	Plume and hydraulic conductivity distributions are less critical	May need to consider the degree of hydraulic and contaminant vertical distribution definition dependent on Data Quality Objectives and sampler type.
Constituent Types Method is Applicable	Mainly recommended for constituents which can be biased by turbidity in wells. Applicable for most other contaminants.	Applicable for all sampling parameters. However, if turbidity values are elevated, low-stress approach may be more applicable if constituents of concern are turbidity sensitive.	Constituents of concern will be dependent on the type of sampler.
Data Quality Objectives	1) High resolution of plume definition both vertically and horizontally. 2) Reduce bias from other sampling methods if turbidity is of concern. 3) Target narrow sections of aquifer.	1) Basic site characterization 2) Moderate to high resolution of plume definition (will be dependent on screen length). 3) Target sample composition to represent entire screened/open interval	1) Can be applicable to basic site characterization, depending on sampler and methodology used. 2) Can reduce bias from other sampling methods. 3) May yield high resolution of plume definition.

[1]Hydraulic conductivities of aquifer materials vary from low hydraulic conductivities (clays, silts, very fine sands) to high conductivities (gravels, sands, weathered bedrock zones). This term for the use on this table is subjective, and is more dependent on the drawdown induced in a monitoring well when sampled with a ground-water sampling pump. For instance, in a well being pumped at 4 liters per minute (l/min) with less than 0.1 feet of drawdown, can be considered to have high hydraulic conductivity. A well that can sustain a 0.2 to 0.4 l/min pumping rate, but has more than 0.5 feet of drawdown can be considered to have low hydraulic conductivity. To assign absolute values of hydraulic conductivities to well performance and sustainable pumping rates cannot be completed because of the many factors in monitoring well construction, such as well diameter, screen open area, and length of screen.

[2] See last paragraph under the SAMPLING OBJECTIVES section.

ATTACHMENT 1
Example Sampling Checklist

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SAMPLING CHECKLIST

Well Identification:________________________

Map of Site Included: Y or N
Wells Clearly Identified with Roads: Y or N
Well Construction Diagram Attached: Y or N

Well Construction:

Diameter of Borehole:________ Diameter of Casing:__________
Casing Material:____________ Screen Material:______________
Screen Length:_____________ Total Depth:______________

Approximate Depth to Water:_____________
Maximum Well Development Pumping Rate:_________________
Date of Last Well Development:_____________

Previous Sampling Information:

Was the Well Sampled Previously: Y or N
(If Sampled, Fill Out Table Below)

Table of Previous Sampling Information

Parameter	Previously Sampled	Number of Times Sampled	Maximum Concentration	Notes (include previous purge rates)

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ATTACHMENT 2
Example Ground-Water Sampling Field Sheets

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GROUND-WATER SAMPLING RECORD

Well ID:______________

Station #:______________

Facility Name: Date:____/____/____

Well Depth:__________ Depth to Water:__________ Well Diameter:___________

Casing Material.:__________ Volume Of Water per Well Volume:______________

Sampling Crew:_________________,___________________,__________________,_____________________

Type of Pump:_________ ___________ Tubing Material:__________________ Pump set at _________________ ft.

Weather Conditions:________________________________ NOTES:_________ _______________________

GROUND-WATER SAMPLING PARAMETERS

Time	Water Level	Volume Pumped	Pumping Rate	DO (mg/l)	Temp. (^{0}C)	SEC (µS/cm)	pH	ORP (mV)	Turbidity (NTU)

Other Parameters: ___________________

Sampled at:_______________ Parameters taken with :____

Sample delivered to _____________________________ by ____________________________ at___________.

Sample CRL #:______________ OTR #:______________ ITR #:______________ SAS #:________________

Parameters Collected	Number of Bottles	Bottle Lot Number

Ground Water Sampling Log

Site Name: **Well #:** **Date:**
Well Depth(Ft-BTOC[1]): **Screen Interval**(Ft):

Well Dia.: **Casing Material:** **Sampling Device:**

Pump placement(Ft from TOC[2]):

Measuring Point: **Water level (static)**(Ft):

Water level (pumping)(Ft): **Pump rate**(Liter/min):

Sampling Personnel:

Other info: (such as sample numbers, weather conditions and field notes)

Water Quality Indicator Parameters

Time	Pumping rates (L/Min)	Water level (ft)	DO (mg/L)	ORP (mv)	SEC[3]	Turb. (NTU)	pH	Temp. (C^0)	Volume pumped (L)

Type of Samples collected:

1 casing volume was:
Total volume purged prior to sample collection:
[1]BTOC-Below Top of Casing
[2]TOC-Top of Casing
[3]Specific Electrical Conductance

Stabilization Criteria

D.O.	+/- 0.3 mg/l
Turb.	+/- 10%
S.C.	+/- 3%
ORP	+/- 10 mV
pH	+/- 0.1 unit

ATTACHMENT 3
Example Standard Operating Procedure:

Standard Operating Procedure for Low-Stress (Low Flow)/Minimal Drawdow Ground-Water Sample Collection

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Standard Operating Procedure for Low-Stress (Low-Flow)/ Minimal Drawdown Ground-Water Sample Collection

INTRODUCTION

The collection of "representative" water samples from wells is neither straightforward nor easily accomplished. Ground-water sample collection can be a source of variability through differences in sample personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at ground-water monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample-collection procedures.

The purpose of this standard operating procedure (SOP) is to provide a method that minimizes the impact the purging process has on the ground-water chemistry and the volume of water that is being purged and disposed of during sample collection. This will take place by placing the pump intake within the screen interval and by keeping the drawdown at a minimal level (0.33 feet) (Puls and Barcelona, 1996) until the water quality parameters have stabilized and sample collection is complete. The flow rate at which the pump will be operating will depend upon both hydraulic conductivity of the aquifer and the drawdown with the goal of minimizing the drawdown. The flow rate from the pump during purging and sampling will be at a rate that will not compromise the integrity of the analyte that is being sampled. This sampling procedure may or may not provide a discrete ground-water sample at the location of the pump intake. The flow of ground-water to the pump intake will be dependent on the distribution of the hydraulic conductivity (K) of the aquifer within the screen interval. In order to minimize the drawdown in the monitoring well, a low-flow rate must be used. "Low-Flow" refers to the velocity with which water enters the pump intake from the surrounding formation in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface, which can be affected by flow regulators or restrictions (Puls and Barcelona, 1996). This SOP was developed by the Superfund/RCRA Ground Water Forum and draws from an USEPA's Ground Water Issue Paper, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedure, by Robert W. Puls and Michael J. Barcelona. Also, available USEPA Regional SOPs regarding Low-Stress (Low-Flow) Purging and Sampling were used for this SOP.

SCOPE AND APPLICATION

This SOP should be used primarily at monitoring wells that have a screen or an open interval with a length of ten feet or less and can accept a sampling device that minimizes the disturbance to the aquifer or the water column in the well casing. The screen or open interval should have been optimally located to intercept an existing contaminant plume(s) or along flowpaths of potential contaminant releases. Knowledge of the contaminant distribution within the screen interval is highly recommended and is essential for the success of this sampling procedure. The ground-water samples that are collected using this procedure are acceptable for the analyses of ground-water contaminants that may be found at Superfund and RCRA contamination sites. The analytes may be volatile, semi-volatile organic compounds, pesticides, PCBs, metals, and other inorganic compounds. The screened interval should be located within the contaminant plume(s) and the pump intake should be placed at or near the known source of the contamination within the screened interval. It is critical to place the pump intake in the exact location or depth for each sampling event. This argues for the use of dedicated, permanently installed, sampling devices whenever possible. If this is not possible, then the placement of the pump intake should be positioned with a calibrated sampling pump hose sounded with a weighted-tape or using a pre-measured hose. The pump intake should not be placed near the bottom of the screened interval to avoid disturbing any sediment that may have settled at the bottom of the well.

Water-quality-indicator parameters and water levels must be measured during purging, prior to sample collection. Stabilization of the water-quality-indicator parameters as well as monitoring water levels are a prerequisite to sample collection. The water-quality-indicator parameters that are recommended include the following: specific electrical conductance, dissolved oxygen, turbidity, oxidation-reduction potential, pH, and temperature. The latter two parameters are useful data, but are generally insensitive as purging parameters. Oxidation-reduction potential may not always be appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidation conditions and for fate and transport issues.

Also, when samples are collected for metals, semi-volatile organic compounds, and pesticides, every effort must be made to reduce turbidity to 10 NTUs or less (not just the stabilization of turbidity) prior to the collection of the water sample. In addition to the measurement of the above parameters, depth to water must be measured during purging (U.S. Environmental Protection Agency, 1995).

Proper well construction, development, and maintenance are essential for any ground-water sampling procedure. Prior to conducting the field work, information on the construction of the well and well development should be obtained and that information factored into the site specific sampling procedure. The Sampling Checklist at the end of this attachment is an example of the type of information that is useful.

Stabilization of the water-quality-indicator parameters is the criterion for sample collection. But if stabilization is not occurring and the procedure has been strictly followed, then sample collection can take place once three (minimum) to six (maximum) casing volumes have been removed (Schuller et al., 1981 and U.S. Environmental Protection Agency., 1986; Wilde et al., 1998; Gibs and Imbrigiotta., 1990). The specific information on what took place during purging must be recorded in the field notebook or in the ground-water sampling log.

This SOP is not to be used where non-aqueous phase liquids (NAPL) (immiscible fluids) are present in the monitoring well.

EQUIPMENT

- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for determination of liquid products (NAPL) presence, if needed.
- Steel tape and weight - Used for measuring total depth of well. Lead weight should not be used.
- Sampling pump - Submersible or bladder pumps with adjustable rate controls are preferred. Pumps are to be constructed of inert materials, such as stainless steel and Teflon®. Pump types that are acceptable include gear and helical driven, centrifugal (low-flow type), and air-activated piston. An adjustable rate, peristaltic pump can be used when the depth to water is 20 feet or less.
- Tubing - Teflon® or Teflon®-lined polyethylene tubing is preferred when sampling for organic compounds. Polyethylene tubing can be used when sampling inorganics.
- Power source - If a combustion type (gasoline or diesel-driven) generator is used, it must be placed downwind of the sampling area.
- Flow measurement supplies - flow meter, graduated cylinder, and a stop watch.
- Multi-parameter meter with flow-through cell - This can be one instrument or more contained in a flow-through cell. The water-quality-indicator parameters that are monitored are pH, ORP/Eh, (ORP) dissolved oxygen (DO), turbidity, specific conductance, and temperature. Turbidity readings must be collected before the flow cell because of the potential for sediment buildup, which can bias the turbidity measurements. Calibration fluids for all instruments should be NIST-traceable and there should be enough for daily calibration throughout the sampling event. The inlet of the flow cell must be located near the bottom of the flow cell and the outlet near the top. The size of the flow cell should be kept to a minimum and a closed cell is preferred. The flow cell must not contain any air or gas bubbles when monitoring for the water-quality-indicator parameters.
- Decontamination supplies - Including a reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap will also be needed.
- Sample bottles, sample preservation supplies, sample tags or labels, and chain-of-custody forms.
- Approved Field Sampling and Quality Assurance Project Plan.
- Well construction, field, and water quality data from the previous sampling event.
- Well keys and map of well locations.
- Field notebook, ground-water sampling logs, and calculator. A suggested field data sheet (ground-water sampling record or ground-water sampling log) are provided at the end of this attachment.

- Filtration equipment, if needed. An in-line disposable filter is recommended.
- Polyethylene sheeting placed on ground around the well head.
- Personal protective equipment as specified in the site Health and Safety Plan.
- Air monitoring equipment as specified in the Site Health and Safety Plan.
- Tool box - All needed tools for all site equipment used.
- A 55-gallon drum or container to contain the purged water.

Construction materials of the sampling equipment (bladders, pumps, tubing, and other equipment that comes in contact with the sample) should be limited to stainless steel, Teflon®, glass, and other inert material. This will reduce the chance that sampling materials alter the ground-water where concentrations of the site contaminants are expected to be near the detection limits. The sample tubing diameter should be maximized and the tubing length should be minimized so that the loss of contaminants into and through the tubing walls may be reduced and the rate of stabilization of ground-water parameters is maximized. The tendency of organics to sorb into and out of material makes the appropriate selection of sample tubing material critical for trace analyses (Pohlmann and Alduino, 1992; Parker and Ranney, 1998).

PURGING AND SAMPLING PROCEDURES

The following describes the purging and sampling procedures for the Low-Stress (Low-Flow)/ Minimal Drawdown method for the collection of ground-water samples. These procedures also describe steps for dedicated and non-dedicated systems.

Pre-Sampling Activities (Non-dedicated and dedicated system)

1. Sampling must begin at the monitoring well with the least contamination, generally up-gradient or farthest from the site or suspected source. Then proceed systematically to the monitoring wells with the most contaminated ground water.

2. Check and record the condition of the monitoring well for damage or evidence of tampering. Lay out polyethylene sheeting around the well to minimize the likelihood of contamination of sampling/purging equipment from the soil. Place monitoring, purging and sampling equipment on the sheeting.

3. Unlock well head. Record location, time, date, and appropriate information in a field logbook or on the ground-water sampling log (See attached ground-water sampling record and ground-water sampling log as examples).

4. Remove inner casing cap.

5. Monitor the headspace of the monitoring well at the rim of the casing for volatile organic compounds (VOC) with a photo-ionization detector (PID) or flame ionization detector (FID) and record in the logbook. If the existing monitoring well has a history of positive readings of the headspace, then the sampling must be conducted in accordance with the Health and Safety Plan.

6. Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference measuring point on the well casing with an electronic water level indicator or steel tape and record in logbook or ground-water sampling log. If no reference point is found, measure relative to the top of the inner casing, then mark that reference point and note that location in the field logbook. Record information on depth to ground water in the field logbook or ground-water sampling log. Measure the depth to water a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.

7. Check the available well information or field information for the total depth of the monitoring well. Use the information from the depth of water in step six and the total depth of the monitoring well to calculate the volume of the water in the monitoring well or the volume of one casing. Record information in field logbook or ground-water sampling log.

Purging and Sampling Activities

8A. Non-dedicated system - Place the pump and support equipment at the wellhead and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a predetermined location within the screen interval. The placement of the pump intake should be positioned with a calibrated sampling pump hose, sounded with a weighted-tape, or using a pre-measured hose. Refer to the available monitoring well information to determine the depth and length of the screen interval. Measure the depth of the pump intake while lowering the pump into location. Record pump location in field logbook or ground-water sampling log.

8B. Dedicated system - Pump has already been installed, refer to the available monitoring well information and record the depth of the pump intake in the field logbook or ground-water sampling log.

9. Non-dedicated system and dedicated systems - Measure the water level (water level must be measured to nearest 0.01 feet) and record information on the ground-water sampling log, leave water level indicator probe in the monitoring well.

10. Non-dedicated and dedicated systems - Connect the discharge line from the pump to a flow-through cell. A "T" connection is needed prior to the flow-through cell to allow for the collection of water for the turbidity measurements. The discharge line from the flow-through cell must be directed to a container to contain the purge water during the purging and sampling of the monitoring well.

11. Non-dedicated and dedicated systems - Start pumping the well at a low flow rate (0.2 to 0.5 liter per minute) and slowly increase the speed. Check water level. Maintain a steady flow rate while maintaining a drawdown of less than 0.33 feet (Puls and Barcelona, 1996). If drawdown is greater than 0.33 feet, lower the flow rate. 0.33 feet is a goal to help guide with the flow rate adjustment. It should be noted that this goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience (Puls and Barcelona, 1996).

12. Non-dedicated and dedicated systems - Measure the discharge rate of the pump with a graduated cylinder and a stop watch. Also, measure the water level and record both flow rate and water level on the ground-water sampling log. Continue purging, monitor and record water level and pump rate every three to five minutes during purging. Pumping rates should be kept at minimal flow to ensure minimal drawdown in the monitoring well.

13. Non-dedicated and dedicated systems - During the purging, a minimum of one tubing volume (including the volume of water in the pump and flow cell) must be purged prior to recording the water-quality indicator parameters. Then monitor and record the water-quality- indicator parameters every three to five minutes. The water-quality indicator field parameters are turbidity, dissolved oxygen, specific electrical conductance, pH, redox potential, and temperature. Oxidation-reduction potential may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions. Also, for the final dissolved oxygen measurement, if the readings are less than 1 milligram per liter, it should be collected and analyze with the spectrophotometric method (Wilde et al., 1998 Wilkin et al., 2001), colorimetric or Winkler titration (Wilkin et al., 2001). The stabilization criterion is based on three successive readings of the water quality field parameters; the following are the criteria which must be used:

Parameter	Stabilization Criteria	Reference
pH	+/- 0.1 pH units	Puls and Barcelona, 1996; Wilde et al., 1998
specific electrical conductance (SEC)	+/- 3% S/cm	Puls and Barcelona, 1996
oxidation-reduction potential (ORP)	+/- 10 millivolts	Puls and Barcelona, 1996
turbidity	+/- 10% NTUs (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996; Wilde et al., 1998
dissolved oxygen	+/- 0.3 milligrams per liter	Wilde et al., 1998

Once the criteria have been successfully met indicating that the water quality indicator parameters have stabilized, then sample collection can take place.

14. If a stabilized drawdown in the well can't be maintained at 0.33 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. Under no circumstances should the well be pumped dry. Begin pumping at a lower flow rate, if the water draws down to the top of the screened interval again, turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging, then sampling can proceed next time the pump is turned on. This information should be noted in the field notebook or ground-water sampling log with a recommendation for a different purging and sampling procedure.

15. Non-dedicated and dedicated systems - Maintain the same pumping rate or reduce slightly for sampling (0.2 to 0.5 liter per minute) in order to minimize disturbance of the water column. Samples should be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. Disconnect the pump's tubing from the flow-through cell so that the samples are collected from the pump's discharge tubing. For samples collected for dissolved gases or VOC analyses, the pump tubing needs to be completely full of ground water to prevent the ground water from being aerated as it flows through the tubing. The sequence of the samples is immaterial unless filtered (dissolved) samples are collected and they must be collected last (Puls and Barcelona, 1996). All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container. When filling the VOC samples, a meniscus must be formed over the mouth of the vial to eliminate the formation of air bubbles and head space prior to capping. In the event that the ground water is turbid, (greater then 10 NTUs), a filtered metal (dissolved) sample also should be collected.

If filtered metal sample is to be collected, then an in-line filter is fitted at the end of the discharge tubing and the sample is collected after the filter. The in-line filter must be pre-rinsed following manufacturer's recommendations and if there are no recommendations for rinsing, a minimum of 0.5 to 1 liter of ground water from the monitoring well must pass through the filter prior to sampling.

16A. Non-dedicated system - Remove the pump from the monitoring well. Decontaminate the pump and dispose of the tubing if it is non-dedicated.

16B. Dedicated system - Disconnect the tubing that extends from the plate at the wellhead (or cap) and discard after use.

17. Non-dedicated system - Before locking the monitoring well, measure and record the well depth (to 0.1 feet).

Measure the total depth a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.

18. Non-dedicated and dedicated systems - Close and lock the well.

DECONTAMINATION PROCEDURES

Decontamination procedures for the water level meter and the water quality field parameter sensors.
The electronic water level indicator probe/steel tape and the water-quality field parameter sensors will be decontaminated by the following procedures:

1. The water level meter will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water.

2. Water quality field parameter sensors and flow-through cell will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these probes since they are sensitive. After the sampling event, the flow cell and sensors must be cleaned and maintained per the manufacturer's requirements.

Decontamination Procedure for the Sampling Pump

Upon completion of the ground water sample collection the sampling pump must be properly decontaminated between monitoring wells. The pump and discharge line including support cable and electrical wires which were in contact with the ground water in the well casing must be decontaminated by the following procedure:

1. The outside of the pump, tubing, support cable and electrical wires must be pressure-sprayed with soapy water, tap water, and distilled water. Spray outside of tubing and pump until water is flowing off of tubing after each rinse. Use bristle brush to help remove visible dirt and contaminants.
2. Place the sampling pump in a bucket or in a short PVC casing (4-in. diameter) with one end capped. The pump placed in this device must be completely submerged in the water. A small amount of phosphate-free detergent must be added to the potable water (tap water).
3. Remove the pump from the bucket or 4-in. casing and scrub the outside of the pump housing and cable.
4. Place pump and discharge line back in the 4-in. casing or bucket, start pump and recirculate this soapy water for 2 minutes (wash).
5. Re-direct discharge line to a 55-gallon drum. Continue to add 5 gallons of potable water (tap water) or until soapy water is no longer visible.
6. Turn pump off and place pump into a second bucket or 4-in. casing that contains tap water. Continue to add 5 gallons of tap water (rinse).
7. Turn pump off and place pump into a third bucket or 4-in. casing which contains distilled/deionized water, continue to add 3 to 5 gallons of distilled/ deionized water (final rinse).
8. If a hydrophobic contaminant is present (such as separate phase, high levels of PCBs, etc.), an additional decontamination step, or steps, may be added. For example, an organic solvent, such as reagent-grade isopropanol alcohol may be added as a first spraying/bucket prior to the soapy water rinse/bucket.

FIELD QUALITY CONTROL

Quality control (QC) samples must be collected to verify that sample collection and handling procedures were performed adequately and that they have not compromised the quality of the ground-water samples. The appropriate EPA program guidance must be consulted in preparing the field QC sample requirements for the site-specific Quality Assurance Project Plan (QAPP).

There are five primary areas of concern for quality assurance (QA) in the collection of representative ground-water samples:

1. Obtaining a ground-water sample that is representative of the aquifer or zone of interest in the aquifer. Verification is based on the field log documenting that the field water-quality parameters stabilized during the purging of the well, prior to sample collection.
2. Ensuring that the purging and sampling devices are made of materials, and utilized in a manner that will not interact with or alter the analyses.
3. Ensuring that results generated by these procedures are reproducible; therefore, the sampling scheme should incorporate co-located samples (duplicates).
4. Preventing cross-contamination. Sampling should proceed from least to most contaminated wells, if known. Field equipment blanks should be incorporated for all sampling and purging equipment, and decontamination of the equipment is therefore required.
5. Properly preserving, packaging, and shipping samples.

All field QC samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The chain-of-custody procedures for the QC samples will be identical to the field ground-water samples. The following are QC samples that must be collected during the sampling event:

	Sample Type	Frequency
●	Field duplicates	1 per 20 samples
●	Matrix spike	1 per 20 samples
●	Matrix spike duplicate	1 per 20 samples
●	Equipment blank	per Regional require- ments or policy
●	Trip blank (VOCs)	1 per sample cooler
●	Temperature blank	1 per sample cooler

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site Health and Safety Plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phase through the use of appropriate personal protective equipment.

Depending on the type of contaminants expected or determined in previous sampling efforts, the following safe work practices will be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and incidental ingestion of, purge water.
2. Use protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.
2. Pre-survey the well head space with an appropriate device as specified in the site Health and Safety Plan.
3. If monitoring results indicate elevated organic constituents, sampling activities may be conducted in level C protection. At a minimum, skin protection will be afforded by disposable protective clothing, such as Tyvek®.

General practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when filling pre-acidified VOA bottles, hydrochloric acid fumes may be released and should not be inhaled.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once ground-water sampling has been completed. These activities include, but are not limited to the following:

1. Ensuring that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
2. Processing all sample paperwork, including copies provided to the Regional Laboratory, Sample Management Office, or other appropriate sample handling and tracking facility.
3. Compiling all field data for site records.
4. Verifying all analytical data processed by the analytical laboratory against field sheets to ensure all data has been returned to sampler.

REFERENCES

Gibs, J. and T.E. Imbrigiotta, 1990, Well-Purging Criteria for Sampling Purgeable Organic Compounds; Ground Water, Vol. 28, No. 1, pp 68-78.

Pohlmann, K.F. and A.J. Alduino, 1992, GROUND-WATER ISSUE PAPER: Potential Sources of Error in Ground-Water Sampling at Hazardous Waste Sites, US Environmental Protection Agency. EPA/540/S-92/019.

Puls, R.W. and M.J. Barcelona, 1996, GROUND-WATER ISSUE PAPER: Low-Flow (Minimal Draw-down) Ground-Water Sampling Procedure, US Environmental Protection Agency. EPA/540/S-95/504, 12 pp.

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.

Parker, L.V. and T.A. Ranney, 1998, Sampling Trace-Level Organic Solutes with Polymeric Tubing: Part 2, Dynamic Studies; Ground Water Monitoring and Remediation, Vol. 18, No. 1, pp. 148-155.

U.S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document; OSWER-9950.1, U.S. Government Printing Office, Washington, D.C., 208 pp., appendices.

U.S. Environmental Protection Agency, 1995, Ground Water Sampling - A Workshop Summary, Texas, November 30-December 2, 1993, EPA/600/R-94/205, 146 pp.

U.S. Environmental Protection Agency Region 1, 1996, Low Stress (low flow) Purging and Sampling Prodedure for the Collection of Ground water Samples From Monitoring Wells, SOP#: GW 0001, July 30, 1996.

U.S. Environmental Protection Agency Region 2, 1998, Ground Water Sampling Procedure Low Stress (Low Flow) Purging and Sampling, GW Sampling SOP Final, March 16, 1998.

Wilde, F.D., D.B. Radtke, J.Gibs and R.T. Iwatsubo, eds., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, variously paginated.

Wilkin, R.T., M.S. McNeil, C.J. Adair and J.T. Wilson, 2001, Field Measurement of Dissolved Oxygen: A Comparison of Methods, Ground Water Monitoring and Remediation, Vol. 21, No. 4, pp. 124-132.

SAMPLING CHECKLIST

Well Identification:________________________

Map of Site Included: Y or N
Wells Clearly Identified with Roads: Y or N
Well Construction Diagram Attached: Y or N

Well Construction:

Diameter of Borehole:________ Diameter of Casing:__________
Casing Material:____________ Screen Material:______________
Screen Length:_____________ Total Depth:______________

Approximate Depth to Water:_____________
Maximum Well Development Pumping Rate:_________________
Date of Last Well Development:_____________

Previous Sampling Information:

Was the Well Sampled Previously: Y or N
(If Sampled, Fill Out Table Below)

Table of Previous Sampling Information				
Parameter	Previously Sampled	Number of Times Sampled	Maximum Concentration	Notes (include previous purge rates)

Ground Water Sampling Log

Site Name: **Well #:** **Date:**
Well Depth(Ft-BTOC[1]): **Screen Interval**(Ft):

Well Dia.: **Casing Material:** **Sampling Device:**

Pump placement(Ft from TOC[2]):

Measuring Point: **Water level (static)**(Ft):

Water level (pumping)(Ft): **Pump rate**(Liter/min):

Sampling Personnel:

Other info: (such as sample numbers, weather conditions and field notes)

Water Quality Indicator Parameters

Time	Pumping rates (L/Min)	Water level (ft)	DO (mg/L)	ORP (mv)	Turb. (NTU)	SEC[3] (S/cm)	pH	Temp. (C^0)	Volume pumped (L)

Type of Samples collected:

1 casing volume was:

Total volume purged prior to sample collection:

Stabilization Criteria

D.O.	+/- 0.3 mg/l
Turb.	+/- 10%
S.C.	+/- 3%
ORP	+/- 10 mV
pH	+/- 0.1 unit

[1]**BTOC-Below Top of Casing**
[2]**TOC-Top of Casing**
[3]**Specific Electrical Conductance**

ATTACHMENT 4
Example Standard Operating Procedure:

Standard Operating Procedure for the Standard/Well-Volume Method for Collecting a Ground-Water Sample

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Standard Operating Procedure for the Well-Volume Method for Collecting a Ground-Water Sample

INTRODUCTION

The collection of "representative" water samples from wells is neither straightforward nor easily accomplished. Ground-water sample collection can be a source of variability through differences in sampling personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at ground-water monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample-collection procedures.

The objectives of the sampling procedures described in this document are to minimize changes in ground-water chemistry during sample collection and transport to the laboratory and to maximize the probability of obtaining a representative, reproducible ground-water sample. Sampling personnel may benefit from a working knowledge of the chemical processes that can influence the concentration of dissolved chemical species.

The well-volume method described in this standard operating procedure (SOP) provides a reproducible sampling technique with the goal that the samples obtained will represent water quality over an entire open interval of a short-screened (ten feet or less) well. This technique is appropriate for long-term and detection monitoring of formation water quality. The resulting sample generally represents a composite of the screened interval, and thus integrates small-scale vertical heterogeneities of ground-water chemistry. This sampling technique also is useful for screening purposes for detection monitoring of contaminants in the subsurface. However, the detection of a low concentration of contaminant in a thin contaminated zone or with long well screens may be difficult and should be determined using detailed vertical profiling techniques.

This method may not be applicable for all ground-water-sampling wells, such as wells with very low yields, fractured rock, and some wells with turbidity problems. As always, site-specific conditions and objectives should be considered prior to the selection of this method for sampling.

SCOPE AND APPLICATION

The objective of a good sampling program should be the collection of a representative sample of the current ground-water conditions over a known or specified volume of aquifer. To meet this objective, the sampling equipment, the sampling method, the monitoring well construction, monitoring well operation and maintenance, and sample-handling procedures should not alter the chemistry of the sample.

An example of how a site's Data Quality Objectives (DQOs) for a characterization sampling effort might vary from those of a remediation monitoring sampling effort could be a difference of how much of the screened interval or aquifer should be sampled. A site characterization objective may be to collect a sample that represents a composite of the entire (or as close as is possible) screened interval of the monitoring well.

Additionally, the site characterization may require a large suite of contaminants to be sampled and analyzed, whereas, the remediation monitoring program may require fewer contaminants sampled and analyzed. These differences may dictate the type of sampling equipment used, the type of information collected, and the sampling protocol.

This sampling method described is for monitoring wells. However, this method should not be used for water-supply wells with a water-supply pump, with long-screened wells in complex hydrogeologic environments (such as fractured rock), or wells with separate phases of liquids (such as a Dense or Light Non-Aqueous Phase Liquids) present within the screened interval.

EQUIPMENT

- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for measuring separate phase liquids, if needed. Pressure transducer and data logger optional for frequent depth-to-water measuring in same well.
- Steel tape and weight - Used for measuring total depth of well. Lead weights should not be used.
- Sampling pump - Submersible or bladder pumps with adjustable rate controls are preferred. Pumps

are to be constructed of inert materials, such as stainless steel and Teflon®. Pump types that are acceptable include gear and helical driven, centrifugal (low-flow type), and air-activated piston. Adjustable rate, peristaltic pumps can be used when the depth to water is 20 feet or less.

- Tubing - Inert tubing should be chosen based on the types and concentrations of contaminants present, or expected to be present in the monitoring well. Generally, Teflon®-based tubing is recommended when sampling for organic compounds. Polyethylene or Teflon® tubing can be used when sampling for inorganic constituents.
- Power source - If a combustion type (gasoline or diesel-driven) device is used, it must be located downwind of the point of sample collection. If possible, it should also be transported to the site and sampling location in a different vehicle from the sampling equipment.
- Flow-measurement equipment - Graduated cylinder or bucket and a stop watch, or a flow meter that can be disconnected prior to sampling.
- Multi-parameter meter with flow-through cell - This can be one instrument or multiple probes/instruments contained in a flow-through cell. The water-quality-indicator parameters that are measured in the field are pH, oxidation/reduction potential (ORP, redox, or Eh), dissolved oxygen (DO), turbidity, specific electrical conductance (SEC), and temperature. Calibration standards for all instruments should be NIST-traceable, within expiration dates of the solutions, and sufficient for daily calibration throughout the sampling collection.
- Decontamination supplies - A reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap also will be needed.
- Sample bottles, sample preservation supplies and laboratory paperwork. Also, several coolers, and sample packing supplies (absorbing packing material, plastic baggies, etc.).
- Approved plans and background documents - Approved Field Sampling Plan, Quality Assurance Project Plan, well construction data, field and water-quality data from the previous sampling collection.
- Site Access/Permission documentation for site entry.
- Well keys and map showing locations of wells.
- Field notebook, field data sheets and calculator. A suggested field data sheet is provided at the end of this attachment.
- Filtration equipment - If needed, this equipment should be an in-line disposable filter used for the collection of samples for analysis of dissolved constituents.
- Polyethylene sheeting - Used for decontamination stations and during sampling to keep equipment clean.
- Site Health and Safety Plan and required equipment - The health and safety plan along with site sign-in sheet should be on site and be presented by the site health and safety officer. Personnel-protective and air-monitoring equipment specified in the Site Health and Safety Plan should be demonstrated, present and in good working order on site at all times.
- Tool box - All needed tools for all site equipment used.
- A 55-gallon drum or container to contain the purged water.

Construction materials of the sampling equipment (bladders, pump, bailers, tubing, etc.) should be limited to stainless steel, Teflon®, glass, and other inert materials when concentrations of the site contaminants are expected within the detection limit range. The sample tubing thickness and diameter should be maximized and the tubing length should be minimized so that the loss of contaminants absorbed to and through the tubing walls may be reduced and the rate of stabilization of ground-water parameters is maximized. The tendency of organics to sorb into and out of many materials makes the appropriate selection of sample tubing materials critical for these trace analyses (Pohlmann and Alduino, 1992; Parker and Ranney, 1998).

Generally, wells should be purged and sampled using the same positive-displacement pump and/or a low-flow submersible pump with variable controlled flow rates and constructed of chemically inert materials. If a pump cannot be used because the recovery rate of the well is so low (less than 100 to 200 ml/min) and the volume of the water to be removed is minimal (less than 5 feet of water in a small-diameter well), then a Teflon® bailer, with a double check valve and bottom-emptying device with a control-flow check valve may be used to obtain the samples. Otherwise, a bailer should not be used when sampling for volatile organics because of the potential bias introduced during sampling (Yeskis et al., 1988; Pohlmann et al., 1990; Tai et al., 1991). Bailers also should be avoided when sampling for metals because repeated bailer deployment has the potential to increase turbidity, which biases concentrations of inorganic constituents. Dedicated sampling pumps are recommended for metals sampling (Puls et al., 1992).

In addition, for wells with long riser pipes above the well screen, the purge volumes may be reduced by using packers above the pumps. The packer materials should be compatible with the parameters to be analyzed. These packers should be used only on wells screened in highly permeable materials, because of the lack of ability to monitor water levels in the packed interval. Otherwise, if pumping rates exceed the natural aquifer recovery rates into the packed zone, a vacuum or negative pressure zone may develop. This may result in a failure of the seal by the packer and/or a gaseous phase may develop, that may bias any sample taken.

PURGING AND SAMPLING PROCEDURE

WATER-LEVEL MEASUREMENTS

The field measurements should include total well depth and depth to water from a permanently marked reference point.

TOTAL WELL DEPTH

The depth of each well should be measured to the nearest one-tenth of a foot when using a steel tape with a weight attached and should be properly recorded. The steel tape should be decontaminated before use in another well according to the site specific protocols. A concern is that when the steel tape and weight hit the bottom of the well, sediment present on the bottom of a well is stirred up, thus increasing turbidity, which will affect the sampling results. In these cases, as much time as possible should be allowed prior to sampling, such as a minimum of 24 hours. If possible, total well depth measurements can be completed after sampling (Puls and Barcelona, 1996). The weight of electric tapes is generally too light to determine accurate total well depth. If the total well depth is greater than 200 feet, stretching of the tape must be taken into consideration.

DEPTH TO WATER

All water levels should be measured from the reference point by use of a weighted steel tape and chalk or an electronic water-level indicator (a detailed discussion of the pros and cons of the different water level devices is provided in Thornhill, 1989). The steel tape is a more accurate method to take water levels, and is recommended where shallow flow gradients (less than 0.05 feet/feet) or deep wells are encountered. However, in those cases where large flow gradients or large fluctuations in water levels are expected, a calibrated electric tape is acceptable. The water level is calculated using the well's surveyed reference point minus the measured depth-to-water and should be measured to the nearest one hundredth of a foot.

The depth-to-water measurement must be made in each well to be sampled prior to any other activities at the well (such as bailing, pumping, and hydraulic testing) to avoid bias to the measurement. All readings are to be recorded to the nearest one hundredth of a foot. When possible, depth-to-water and total well depth measurements should be completed at the beginning of a ground-water sampling program, which will allow any turbidity to settle and allow a more synoptic water-level evaluation. However, if outside influences (such as tidal cycles, nearby pumping effects, or major barometric changes) may result in significant water-level changes in the time between measurement and sampling, a water-level measurement should be completed immediately prior to sampling. In addition, the depth-to-water measurement during purging should be recorded, with the use of a pressure transducer and data logger sometimes more efficient (Barcelona et al., 1985, Wilde et al., 1998).

The time and date of the measurement, point of reference, measurement method, depth-to-water measurement, and any calculations should be properly recorded in field notebook or sampling sheet.

STATIC WATER VOLUME

From the information obtained for casing diameter, total well depth and depth-to-water measurements, the volume of water in the well is calculated. This value is one criteria that may be used to determine the volume of water to be purged from the well before the sample is collected.

The static water volume may be calculated using the following formula:

$$V = r^2h(0.163)$$

Where:

V	=	static volume of water in well (in gallons)
r	=	inner radius of well casing (in inches)
h	=	length of water column (in feet) which is equal to the total well depth minus depth to water.
0.163	=	a constant conversion factor that compensates for the conversion of the casing radius from inches to feet for 2-inch diameter wells and the conversion of cubic feet to gallons, and pi (π). This factor would change for different diameter wells.

Static water volumes also may be obtained from various sources, such as Appendix 11.L in Driscoll (1986).

WELL PURGING

PURGE VOLUMES

In most cases, the standing water in the well casing can be of a different chemical composition than that contained in the aquifer to be sampled. Solutes may be adsorbed or desorbed from the casing material, oxidation may occur, and biological activity is possible. Therefore, the stagnant water within the well must be purged so that water that is representative of the aquifer may enter the well.

The removal of at least three well volumes is suggested (USEPA, 1986; Wilde et al., 1998). The amount of water removed may be determined by collecting it in a graduated pail of known volume to determine pumping rate and time of pumping. A flow meter may also be used, as well as capturing all purged water in a container of known volume.

The actual number of well volumes to be removed is based on the stabilization of water-quality-indicator parameters of pH, ORP, SEC, DO, and turbidity. The water initially pumped is commonly turbid. In order to keep the turbidity and other probes from being clogged with the sediment from the turbid water, the flow-through cell should be bypassed initially for the first well volume. These measurements should be taken and recorded every ½ well volume after the removal of 1 to 1 ½ well volume(s). Once three successive readings of the water-quality-indicator parameters provided in the table have stabilized, sampling may begin. The water-quality-indicator parameters that are recommended include pH and temperature, but these are generally insensitive to indicate completion of purging since they tend to stabilize rapidly (Puls and Barcelona, 1996). ORP may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions, and for some fate and transport issues. When possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs). For final DO measurements, if the readings are less than 1 milligram per liter, they should be collected with the spectrophotometric method (Wilde et al., 1998, Wilkin et al., 2001), colorimetric or Winkler titration (Wilkin et al., 2001). All of these water-quality-indicator parameters should be evaluated against the specifications of the accuracy and resolution of the instruments used. No more than six well volumes should be purged, to minimize the over pumping effects described by Gibs and Imbrigiotta (1990).

Purging Methods

In a well that is not being pumped, there will be little or no vertical mixing in the water column between sampling events, and stratification may occur. The water in the screened section may mix with the ground water due to normal flow patterns, but the water above the screened section will remain isolated and become stagnant. Persons sampling should realize that stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in unrepresentative water quality. To safeguard against collecting nonrepresentative stagnant water in a sample, the following guidelines and techniques should be adhered to during sample collection:

Table of Stabilization Criteria with References for Water-Quality-Indicator Parameters

Parameter	Stabilization Criteria	Reference
pH	+/- 0.1	Puls and Barcelona, 1996; Wilde et al., 1998
specific electrical conductance (SEC)	+/- 3%	Puls and Barcelona, 1996
oxidation-reduction potential (ORP)	+/- 10 millivolts	Puls and Barcelona, 1996
turbidity	+/- 10% (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996; Wilde et al., 1998
dissolved oxygen (DO)	+/- 0.3 milligrams per liter	Wilde et al., 1998

1. As a general rule, monitoring wells should be pumped or bailed (although bailing is to be strongly avoided) prior to collecting a sample. Evacuation of a minimum of three volumes of water in the well casing is recommended for a representative sample. In a high-yielding ground-water formation where there is no stagnant water in the well above the screened section (commonly referred to as a water-table well), evacuation prior to sample withdrawal is not as critical but serves to field rinse and condition sampling equipment. The purge criteria has been described previously and will be again in the SAMPLING PROCEDURES section on the following page. The rate of purging should be at a rate and by a method that does not cause aeration of the water column and should not exceed the rate at which well development was completed.

2. For wells that can be pumped or bailed to dryness with the sampling equipment being used, the well should be evacuated to just above the well screen interval and allowed to recover prior to sample withdrawal. (Note: It is important not to completely dewater the zone being sampled, as this may allow air into that zone which could result in negative bias in organic and metal constituents.) If the recovery rate is fairly rapid and time allows, evacuation of more than one volume of water is preferred.

3. A non-representative sample also can result from excessive prepumping of the monitoring well. Stratification of the contaminant concentrations in the ground-water formation may occur or heavier-than-water compounds may sink to the lower portions of the aquifer. Excessive pumping can decrease or increase the contaminant concentrations from what is representative of the sampling point of interest, as well as increase turbidity and create large quantities of waste water.

The method used to purge a well depends on the inner diameter, depth-to-water level, volume of water in the well, recovery rate of the aquifer, and accessibility of the well to be sampled. The types of equipment available for well evacuation include hand-operated or motor-driven suction pumps, peristaltic pumps, submersible pumps, and bailers made of various materials, such as stainless steel and Teflon®. Whenever possible, the same device used for purging the well should be left in the well and used for sampling, generally in a continual manner from purging directly to sampling without altering position of the sampling device or turning off the device.

When purging/sampling equipment must be reused in other wells, it should be decontaminated consistent with the decontamination procedures outlined in this document. Purged water should be collected and screened with air-monitoring equipment as outlined in the site health and safety plan, as well as water-quality field instruments. If these parameters and/or the facility background data suggest that the water is hazardous, it should be contained and disposed of properly as determined on a site-specific basis.

During purging, water-level measurements should be recorded regularly for shallow wells, typically at 15- to 30-second intervals. These data may be useful in computing aquifer transmissivity and other hydraulic characteristics, and for adjusting purging rates. In addition, these data will assure that the water level doesn't fall below the pump intake level

SAMPLING PROCEDURES

Ground-water sample collection should take place immediately following well purging. Preferably, the same device should be used for sample collection as was used for well purging, minimize further disturbance of the water column, and reduce volatilization and turbidity. In addition, this will save time and avoid possible contamination from the introduction of additional equipment into the well, as well as using equipment materials already equilibrated to the ground water. Sampling should occur in a progression from the least to most contaminated well, if known, when the same sampling device is used.

The sampling procedure is as follows:

1) Remove locking well cap. Note location, time of day, and date in field notebook or on an appropriate log form.
2) Note wind direction. Stand upwind from the well to avoid contact with gases/vapors emanating from the well.
3) Remove well casing cap.
4) If required by site-specific conditions, monitor headspace of well with appropriate air-monitoring equipment to determine presence of volatile organic compounds or other compounds of concern and record in field logbook.
5) If not already completed, measure the water level from the reference measuring point on the well casing or protective outer casing (if inner casing not installed or inaccessible) and record it in the field notebook. Alternatively, if no reference point exists, note that the water level measurement is from the top of the outer protective casing, top of inside riser pipe, ground surface, or some other position on the well head. Have a permanent reference point established as soon as possible after sampling. Measure at least twice to confirm measurement; the measurement should agree within 0.01 feet or re-measure. Decontaminate the water-level-measuring device.
6) If not already completed, measure the total depth of the well (at least twice to confirm measurement; the measurement should agree within 0.01 feet or re-measure) and record it in the field notebook or on log form. Decontaminate the device used to measure total depth. If the total well depth has been measured recently (in the past year), then measure it at the conclusion of sampling.
7) Calculate the volume of water in the well and the volume to be purged using the formula previously provided.
8) Lay plastic sheeting around the well to minimize the likelihood of contamination of equipment from soil adjacent to the well.
9) Rinse the outside of sampling pump with distilled water and then, while lowering the pump, dry it with disposable paper towels.
10) Lower the pump (or bailer) and tubing down the well. The sampling equipment should never be dropped into the well because this will cause degassing of the water upon impact. This may also increase turbidity, which may bias the metals analysis. The lowering of the equipment should be slow and smooth!
11) The pump should be lowered to a point just below the water level. If the water level is above the screened interval, the pump should be above the screened interval for the reasons provided in the purging section.
12) Turn the pump on. The submersible pumps should be operated in a continuous, low-flow manner so that they do not produce pulsating flows, which cause aeration in the discharge tubing, aeration upon discharge, or resuspension of sediments at the bottom of the well. The sampling pump flow rates should be lower than or the same as the purging rates. The purging and sampling rates should not be any greater than well development rates.
13) Water levels should be monitored during pumping to ensure that air does not enter the pump and to help determine an appropriate purging rate.
14) After approximately one to two well volumes are removed, a flow-through cell will be hooked up to the discharge tubing of the pump. If the

well discharge water is not expected to be highly turbid, contain separate liquid phases, or minimal bacterial activitiy that may coat or clog the electrodes within the flow-through cell, then the cell can be immediately hooked up to the discharge tubing. This cell will allow measurements of water-quality-indicator parameters without allowing contact with the atmosphere prior to recording the readings for temperature, pH, ORP, SEC, DO and turbidity.

15) Measurements for temperature, pH, ORP, SEC, DO, and turbidity will be made at each one-half well volume removed. Purging may cease when measurements for all five parameters have stabilized (provided in the earlier table) for three consecutive readings.

16) If the water level is lowered to the pump level before three volumes have been removed, the water level will be allowed to recover for 15 minutes, and then pumping can begin at a lower flow rate. If the pump again lowers the water level to below the pump intake, the pump will be turned off and the water level allowed to recover for a longer period of time. This will continue until a minimum of two well volumes are removed prior to taking the ground-water sample.

17) If the water-quality-indicator parameters have stabilized, sample the well. Samples will be collected by lowering the flow rate to a rate that minimizes aeration of the sample while filling the bottles (approximately 300 ml/min). Then a final set of water-quality-indicator parameters is recorded. The pump discharge line is rapidly disconnected from the flow-through cell to allow filling of bottles from the pump discharge line. The bottles should be filled in the order of volatile organic compounds bottles first, followed by semi-volatile organic compound's/pesticides, inorganics, and other unfiltered samples. Once the last set of samples is taken, if filtering is necessary, an in-line disposable filter (with appropriately chosen filter size) will be added to the discharge hose of the pump. Then the filtered samples will be taken. If a bailer is used for obtaining the samples, filtering occurs at the sampling location immediately after the sample is obtained from the bailer by using a suction filter. The first one-half to one liter of sample taken through the filter will not be collected, in order to assure the filter media is acclimated to the sample. If filtered samples are collected, WITHOUT EXCEPTION, filtering should be performed in the field as soon as possible after collection, and not later in a laboratory.

18) All appropriate samples that are to be cooled, are put into a cooler with ice immediately. All of the samples should not be exposed to sunlight after collection. Keep the samples from freezing in the winter when outside temperatures are below freezing. The samples, especially organics, cyanide, nutrients, and other analytes with short holding times, are recommended to be shipped or delivered to the laboratory daily. Ensure that the appropriate samples that are to be cooled remain at 4°C, but do not allow any of the samples to freeze.

19) If a pump cannot be used because the recovery rate is slow and the volume of the water to be removed is minimal (less than 5 feet of water), then a Teflon® bailer, with a double check valve and bottom-emptying device with a control-flow check valve will be used to obtain the samples. The polypropylene rope used with the bailer will be disposed of following the completion of sampling at each well.

20) The pump is removed from the well and decontaminated for the next sampling location.

Additional precautions to ensure accurate and representative sample collection are as follows:

- Check valves on bailers, if bailers are used, should be designed and inspected to ensure that fouling problems do not reduce delivery capabilities or result in aeration of the sample.
- The water should be transferred to a sample container in a way that will minimize agitation and aeration.
- If the sample bottle contains no preservatives, the bottle should be rinsed with sample water, which is discarded before sampling. Bottles for sample analyses that require preservation should be prepared before they are taken to the well. Care should be taken to avoid overfilling bottles so that the preservative is not lost. The pH should be checked and more preservatives added to inor-

ganic sample bottles, if needed. VOA bottles that do not meet the ph requirements need to be discarded and new sample bottles with more preservative added should be prepared immediately.

- Clean sampling equipment should not be placed directly on the ground or other contaminated surfaces either prior to sampling or during storage and transport.

Special Consideration for Volatile Organic Compound Sampling

The proper collection of a sample for dissolved volatile organics requires minimal disturbance of the sample to limit volatilization and therefore a loss of volatiles from the samples. Preferred retrieval systems for the collection of un-biased volatile organic samples include positive displacement pumps, low-flow centrifugal pumps, and some in-situ sampling devices. Field conditions and other constraints will limit the choice of appropriate systems. The principal objective is to provide a valid sample for analysis, one that has been subjected to the least amount of turbulence possible.

1) Fill each vial to just overflowing. Do not rinse the vial, nor excessively overflow it, as this will effect the pH by diluting the acid preservative previously placed in the bottle. Another option is to add the acid at the well, after the sample has been collected. There should be a convex meniscus on the top of the vial.
2) Do not over tighten and break the cap.
3) Invert the vial and tap gently. Observe the vial closely. If an air bubble appears, discard the sample and collect another. It is imperative that no entrapped air remains in the sample vial. Bottles with bubbles should be discarded, unless a new sample cannot be collected, and then the presence of the bubble should be noted in the field notes or field data sheet. If an open sample bottle is dropped, the bottle should be discarded.
4) Orient the VOC vial in the cooler so that it is lying on its side, not straight up.
5) The holding time for VOCs is 14 days. It is recommended that samples be shipped or delivered to the laboratory daily. Ensure that the samples remain at 4°C, but do not allow the samples to freeze.

Field Filtration of Turbid Samples

The USEPA recognizes that in some hydrogeologic environments, even with proper well design, installation, and development, in combination with the low-flow rate purging and sampling techniques, sample turbidity cannot be reduced to ambient levels. The well construction, development, and sampling information should be reviewed by the Regional geologists or hydrologists to see if the source of the turbidity problems can be resolved or if alternative sampling methods should be employed. If the water sample is excessively turbid, the collection of both filtered and unfiltered samples, in combination with turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pumping rate, and drawdown data is recommended. The filter size used to determine TSS and TDS should be the same as used in the field filtration. An in-line filter should be used to minimize contact with air to avoid precipitation of metals. The typical filter media size used is 0.45 µm because this is commonly accepted as the demarcation between dissolved and non-dissolved species. Other filter sizes may be appropriate, but their use should be determined based on site-specific criteria (examples include grain-size distribution, ground-water flow velocities, mineralogy) and project DQOs. Filter sizes up to 10.0 µm may be warranted because larger size filters may allow particulates that are mobile in ground water to pass through (Puls and Powell, 1992). The changing of filter media size may limit the comparability of the data obtained with other data sets and may affect their use in some geochemical models. Filter media size used on previous data sets from a site, region, or aquifer and the DQOs should be taken into consideration. The filter media used during the ground-water sampling program should be collected in a suitable container and archived because potential analysis of the media may be helpful for the determination of particulate size, mineralogy, etc.

The first 500 to 1000 milliliters of sample taken through the filter, depending on sample turbidity, will not be collected for a sample, in order to ensure that the filter media has equilibrated to the sample. Manufacturers' recommendations also should be consulted. Because bailers have been shown to increase turbidity while purging and sampling, they should be avoided when sampling for trace element, metal, PCB, and pesticide constituents. If portable sampling pumps are used, the pumps should be gently lowered to the sampling depth desired, carefully avoiding being lowered to the bottom of the well. The pumps, once placed in the well, should not be moved to allow any particles mobilized by pump placement to settle. Dedicated sampling equipment installed in the well prior to the commencement of the sampling activities is one of the recommended methods to reduce turbidity artifacts (Puls and Powell, 1992; Kearl et al., 1992; Puls et al., 1992; Puls and Barcelona, 1996).

DECONTAMINATION PROCEDURES

Once removed from the well, the purging and sampling pumps should be decontaminated by scrubbing with a brush and a non-phosphate soapy-water wash, rinsed with water, and rinsed with distilled water to help ensure that there is no cross-contamination between wells. The step-by-step procedure is:

1) Pull pump out of previously sampled well (or out of vehicle) and use three pressure sprayers filled with soapy water, tap water, and distilled water. Spray outside of tubing and pump until water is flowing off of tubing after each rinse. Use bristle brush to help remove visible dirt, contaminants, etc.
2) Have three long PVC tubes with caps or buckets filled with soapy water, tap water and distilled water. Run pump in each until approximately 2 to 3 gallons of each decon solution is pumped through tubing. Pump at low rate to increase contact time between the decon solutions and the tubing.
3) Try to pump decon solutions out of tubing prior to next well. If this cannot be done, compressed air may be used to purge lines. Another option is to install a check valve in the pump line (usually just above the pump head) so that the decon solutions do not run back down the well as the pump is lowered down the next well.
4) Prior to lowering the pump down the next well, spray the outside of the pump and tubing with distilled water. Use disposable paper towels to dry the pump and tubing.
5) If a hydrophobic contaminant is present (such as separate phase, high levels of PCBs, etc.), an additional decon step, or steps, may be added. For example, an organic solvent such as reagent-grade isopropanol alcohol may be added as a first rinse prior to the soapy water rinse.

If the well has been sampled with a bailer that is not disposable, the bailer should be cleaned by washing with soapy water, rinsing with tap water, and finally rinsing with distilled water. Bailers are most easily cleaned using a long-handled bottle brush.

It is especially important to clean thoroughly the portion of the equipment that will be in contact with sample water. In addition, a clean plastic sheet should be placed adjacent to or around the well to prevent surface soils from coming in contact with the purging equipment. The effects of cross-contamination also can be minimized by sampling the least contaminated well first and progressing to the more contaminated ones. The bailer cable/rope (if a bailer is used) and plastic sheet should be properly discarded, as provided in the site health and safety plan, and new materials provided for the next well.

FIELD QUALITY CONTROL

The quality assurance (QA) targets for precision and accuracy of sampling programs are based on accuracy and precision guidelines established by the USEPA. When setting targets, keep in mind that all measurements must be made so that the results are representative of the sample water and site-specific conditions. Various types of blanks are used to check the cleanliness of the field-handling methods. These are known as field blanks, and include field equipment blanks and transport blanks. Other QA samples include spike samples and duplicates.

There are five primary areas of concern for QA in the collection of representative ground-water samples:

1. Obtaining a sample that is representative of water in the aquifer or targeted zone of the aquifer. Verify log documentation that the well was purged of the required volume or that the temperature, pH, ORP, SEC, DO and turbidity stabilized before samples were extracted.

2. Ensuring that the purging and sampling devices are made of materials and utilized in a manner that will not interact with or alter the analyses.
3. Generating results that are reproducible. Therefore, the sampling scheme should incorporate co-located samples (duplicates).
4. Preventing cross-contamination. Sampling should proceed from least to most contaminated wells, if known. Field equipment blanks should be incorporated for all sampling and purging equipment; decontamination of the equipment is therefore required.
5. Ensuring that samples are properly preserved, packaged, and shipped.

FIELD EQUIPMENT BLANKS

To ensure QA and quality control, a field equipment blank must be included in each sampling run, or for every twenty samples taken with the sampling device. Equiptment blanks allow for a cross check and, in some cases, quantitative correction for imprecision that could arise due to handling, preservation, or improper cleaning procedures.

Equipment blanks should be taken for each sample bottle type that is filled. Distilled water is run through the sampling equipment and placed in a sample bottle (the blank), and the contents are analyzed in the lab like any other sample. Following the collection of each set of twenty samples, a field equipment blank will be obtained. It is generally desirable to collect this field equipment blank after sampling a relatively highly contaminated well. These blanks may be obtained through the following procedure:

a) Following the sampling event, decontaminate all sampling equipment according to the site decontamination procedures and before collecting the blank.
b) VOA field blanks should be collected first, prior to water collected for other TAL/TCL analyses. A field blank must be taken for all analyses.
c) Be sure that there is enough distilled water in the pump so that the field equipment blank can be collected for each analysis.
d) The water used for the field equipment blank should be from a reliable source, documented in the field notebooks, and analyzed as a separate water-quality sample.

TRIP BLANKS

A trip blank should be included in each sample shipment and, at a minimum, one per 20 samples. Bottles, identical to those used in the field, are filled with reagent-grade water. The source of the reagent-grade water should be documented in the field notebooks, including lot number and manufacture. This sample is labeled and stored as though it is a sample. The sample is shipped back to the laboratory with the other samples and analysis is carried out for all the same constituents.

DUPLICATE SAMPLES

Duplicate samples are collected by taking separate samples as close to each other in time and space as practical, and should be taken for every 20 samples collected. Duplicate samples are used to develop criteria for acceptable variations in the physical and chemical composition of samples that could result from the sampling procedure. Duplicate results are utilized by the QA officer and the project manager to give an indication of the precision of the sampling and analytical methods.

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site health and safety plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phases through the use of appropriate personal protective equipment.

Depending on the type of contaminant expected or determined in previous sampling efforts, the following safe work practices will be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and accidental ingestion of, purge water.
2. Wear protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.
2. Pre-survey the well head space with an appropriate device as specified in the Site Health and Safety Plan.
3. If air monitoring results indicate elevated organic constituents, sampling activities may be conducted in Level C protection. At a minimum, skin protection will be afforded by disposable protective clothing, such as Tyvek®.

General practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when filling, pre-preserved VOA bottles, hydrochloric acid fumes may be released and should not be inhaled.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once ground-water sampling has been completed. These activities include, but are not limited to:

- Ensuring that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
- Processing all sample paperwork, including copies provided to Central Regional Laboratory, Sample Management Office, or other appropriate sample handling and tracking facility.
- Compiling all field data for site records.
- Verifying all analytical data processed by the analytical laboratory against field sheets to ensure all data has been returned to sampler.

REFERENCES

Barcelona, M.J., J.P. Gibb, J.A. Hellfrich and E.E. Garske, 1985, Practical Guide for Ground-Water Sampling; U.S. Environmental Protection Agency, EPA/600/2-85/104, 169 pp.

Driscoll, F.G., 1986, Groundwater and Wells, 2nd Ed.; Johnson Division, St. Paul, Minnesota, 1089 pp.

Gibs, J. and T.E. Imbrigiotta, 1990, Well-Purging Criteria for Sampling Purgeable Organic Compounds; Ground Water, Vol. 28, No. 1, pp 68-78.

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, Vol. 8, No. 4, pp. 93-99.

Kearl, P.M., N.E. Korte, and T.A. Cronk, 1992, Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloid Borescope; Ground Water Monitoring Review, Vol. 12, No. 2, pp. 155-161.

Keely, J.F. and K. Boateng, 1987, Monitoring Well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations; Ground Water, Vol. 25, No. 4 pp. 427-439.

McAlary, T.A. and J.F. Barker, 1987, Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials; Ground Water Monitoring Review, Vol. 7, No. 4, pp. 63-68.

Nielson, D.M., 1991, Practical Handbook of Ground-Water Monitoring; Lewis Publishers, 717 pp.

Parker, L.V. and T.A. Ranney, 1998, Sampling Trace-Level Organic Solutes with Polymeric Tubing: Part 2, Dynamic Studies; Ground Water Monitoring and Remediation, Vol. 18, No. 1, pp. 148-155.

Pohlmann, K.F., R.P. Blegen, and J.W. Hess, 1990, Field Comparison of Ground-Water Sampling Devices for Hazardous Waste Sites: An Evaluation using Volatile Organic Compounds; EPA/600/4-90/028, 102 pp.

Pohlmann, K.F. and A.J. Alduino, 1992, GROUND-WATER ISSUE PAPER: Potential Sources of Error in Ground-Water Sampling at Hazardous Waste Sites; US Environmental Protection Agency. EPA/540/S-92/019.

Puls, R.W. and R.M. Powell, 1992, Acquisition of Representative Ground Water Quality Samples for Metals; Ground Water Monitoring Review, Vol. 12, No. 3, pp. 167-176.

Puls, R.W., D.A. Clark, B. Bledsoe, R.M. Powell and C.J. Paul, 1992, Metals in Ground Water: Sampling Artifacts and Reproducibility; Hazardous Waste and Hazardous Materials, Vol. 9, No. 2, pp. 149-162.

Puls, R.W. and M.J. Barcelona, 1996, GROUND-WATER ISSUE PAPER: Low-Flow (Minimal Draw-down) Ground-Water Sampling Procedures; U.S. Environmental Protection Agency, EPA/540/S-95/504, 12 pp.

Tai, D.Y., K.S. Turner, and L.A. Garcia, 1991, The Use of a Standpipe to Evaluate Ground Water Samples; Ground Water Monitoring Review, Vol. 11, No. 1, pp. 125-132.

Thornhill, J.T., 1989, SUPERFUND GROUND WATER ISSUE: Accuracy of Depth to Water Measurements; US Environmental Protection Agency. EPA/540/4-89/002, 3 pp.

U.S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document; OSWER-9950.1, U.S. Government Printing Office, Washington, D.C., 208 pp., appendices.

U.S. Environmental Protection Agency, 1995, Ground Water Sampling-A Workshop Summary, Dallas, Texas, November 30-December 2, 1993, EPA/600/R-94/025, 146 pp.

Wilde, F.D., D.B. Radtke, J.Gibs and R.T. Iwatsubo, eds., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, variously paginated.

Wilkin, R.T., M.S. McNeil, C.J. Adair and J.T. Wilson, 2001, Field Measurement of Dissolved Oxygen: A Comparison of Methods, Ground Water Monitoring and Remediation, Vol. 21, No. 4, pp. 124-132.

Yeskis, D., K. Chiu, S. Meyers, J. Weiss and T. Bloom, 1988, A Field Study of Various Sampling Devices and Their Effects on Volatile Organic Contaminants; Proceedings of the Second National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, National Water Well Association, May, 1988.

GROUND-WATER SAMPLING RECORD

Well ID:_______________

Station #:_______________

Facility Name: Date:____/____/____

Well Depth:___________ Depth to Water:___________ Well Diameter:____________

Casing Material.:___________ Volume Of Water per Well Volume:_______________

Sampling Crew:__________________,____________________,____________________,______________________

Type of Pump:__________ ____________ Tubing Material:___________________ Pump set at __________________ ft.

Weather Conditions:___________________________________ NOTES:__________ _________________________

GROUND-WATER SAMPLING PARAMETERS

Time	Water Level	Volume Pumped	Pumping Rate	DO (mg/l)	Temp. (^{0}C)	SEC (µS/cm)	pH	ORP (mV)	Turbidity (NTU)

Other Parameters: ____________________

Sampled at:________________ Parameters taken with :____

Sample delivered to _______________________________ by _____________________________ at___________.

Sample CRL #:_______________ OTR #:_______________ ITR #:_______________ SAS #:___________________

Parameters Collected	Number of Bottles	Bottle Lot Number