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National Field Manual for the Collection of Water-Quality Data

Chapter A4. COLLECTION OF WATER SAMPLES

Revised 2006

USGS
science for a changing world

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Foreword

The mission of the Water Resources Discipline of the U.S. Geological Survey (USGS) is to provide the information and understanding needed for wise management of the Nation's water resources. Inherent in this mission is the responsibility to collect data that accurately describe the physical, chemical, and biological attributes of water systems. These data are used for environmental and resource assessments by the USGS, other government agencies and scientific organizations, and the general public. Reliable and quality-assured data are essential to the credibility and impartiality of the water-resources appraisals carried out by the USGS.

The development and use of a *National Field Manual* is necessary to achieve consistency in the scientific methods and procedures used, to document those methods and procedures, and to maintain technical expertise. USGS field personnel use this manual to ensure that the data collected are of the quality required to fulfill our mission.

Robert M. Hirsch
Associate Director for Water

GROUND-WATER SAMPLING 4.2

Collecting samples of ground water that accurately represent aquifer conditions requires sampling at appropriate wells and using equipment and methods that maintain the integrity of the sample with respect to the physical, chemical, and biological characteristics of interest. This section provides guidance and protocols for (a) site reconnaissance and establishing site files, (b) avoiding collection of bad data, and (c) ground-water withdrawal up to the point of bottling or processing the sample. USGS procedures for collecting raw or filtered ground-water samples into bottles, sample preservation, and other sample-processing and handling activities are addressed in Chapter A5 (NFM 5), "Processing of Water Samples." Because ground-water sample collection is a continuous process, the information in this chapter overlaps somewhat with that of NFM 5.

For USGS studies, ground-water samples typically are collected either at monitor wells or at public or domestic water-supply wells.[11]

- **Monitor wells** are observation wells[12] that are installed principally for the collection of water samples to assess the physical, chemical, and biological characteristics of formation (aquifer) water. Samples from monitor wells are collected either with portable, low-capacity pumps or with other types of sampling devices designed for water-quality work. Sampling devices can be dedicated for use at a given well or can be installed in the well for the duration of the monitoring effort. (The terms "monitor well" and "monitoring well" are used interchangeably in this field manual.)

[11]Ground-water samples collected using passive or natural-gradient methods or direct-push or cone penetrometer systems are not addressed in this chapter.

[12]Observation wells are wells or piezometers that are installed (usually without a dedicated pump) for the purpose of collecting hydrologic data. The term generally has been applied to wells installed to observe and determine hydrologic characteristics of an aquifer (Lapham and others, 1997).

- **Water-supply wells** are wells that are installed primarily for supply of public, domestic, irrigation, commercial, or industrial water and usually are equipped with a dedicated high-capacity pump. Pumps installed in supply wells generally deliver a large volume of water that is subsampled for water quality. (Although the guidance in this manual focuses on sampling at public or domestic supply wells, similar principles and procedures apply when sampling at irrigation, commercial, or industrial wells, with the caveat that additional safety precautions need to be identified and implemented and equipment requirements reviewed.) Note that supply-well construction materials and methods and the pumps installed can have long-lasting effects on the chemistry of water entering the well from the aquifer (Lapham and others, 1997).

4.2.1 SITE INVENTORY AND SITE FILES

Information about the well and field site is compiled in the office and during site-reconnaissance visits. The information compiled is used by study personnel to help determine site suitability for conducting sampling activities. Site files are then established in the USGS National Water Information System (NWIS) electronic data base[13] and the information compiled is entered into NWIS and is used to create a file for use in the field.

[13]NWIS is the public portal to USGS water resources data (Hubbard, 1992; USGS Water Resources policy memorandum 92.59). NWISWeb displays real-time water-level data (http://waterdata.usgs.gov/nwis/gw), and real-time water-quality data for selected wells (http://waterdata.usgs.gov/nwis/qw) (website accessed June 2, 2006).

Site inventory – In an office inventory, the study team identifies existing wells or candidate sites at which to install wells, examines well-construction records, and compiles additional background information and site or well records. The field evaluation, or site reconnaissance, is used to verify well location, select or reject candidate well(s), determine the suitability of the site to meet study objectives, and become aware of equipment or other requirements needed to address specific site conditions (table 4-6). Site-reconnaissance visits also are used to identify areas of ground-water recharge and discharge; test field equipment; test well-purging and sampling procedures; conduct aquifer tests; make preliminary field measurements (see NFM 6); and identify the presence of target analytes, sources of contamination, and potential matrix interferences.

When conducting site inventories:

- ▶ Be familiar with study objectives and requirements for data collection and quality.
- ▶ Be familiar with the considerations for well selection and (or) installation (table 4-6).
- ▶ Be alert to changes over time that might affect the suitability of the well to meet study needs.
- ▶ Keep in mind the primary criteria for all water-quality studies:
  - — The sample must represent the system, in time and space, intended for study.
  - — Sample integrity must be maintained.

Review safety plans and procedures before leaving for the field (NFM 9).

Table 4-6. Example of ground-water site-inventory activities

Before the site visit
Review considerations for well selection and installation (section 4.2.2; Lapham and others, 1997).
Review background information collected.
Obtain permission to gain access to the site and to collect samples from the well.
Update well files: record changes in ownership and land use.
Contact utility companies (gas, water, and electric) before digging or drilling.
Determine whether the pump may or may not be removed from the well by field personnel (removal is not recommended, as personal safety could be compromised). The owner's permission is required to remove a pump—you could be liable for damage to pump or well.
Be sure that you get information needed about the site that could interfere with or interrupt sampling. For example, • Hours of pump operation and scheduled downtime. • Pumping rate or rates. • Holding tanks or chemical treatments. • Electrical service to the site. • Scheduled maintenance for pumps or related equipment. • Scheduled site maintenance, such as painting, construction, and defoliation. • Seasonal water-level declines that make the well unusable. • Times of denied access; for example, no access while the owner is out of town. • Special site-access needs; for example, clearance with a site owner or site operator, keys to unlock access to the site, animals. • Restrictions on the location.
Before and during the site visit
Record conditions that could compromise study objectives, including potential point or nonpoint sources of contamination. For example, • Nearby wells that could affect well hydraulics. • Condition of well—for example, rusting or punctured casing, poor surface seal. • Has the well been adequately developed? Could well-development artifacts compromise sample integrity? • Land use and land cover or changes in land use and land cover. • Application of salt on nearby roads during winter, or application or use of herbicides and pesticides. • Landfills or other waste-management facilities. • Industrial, commercial, and agricultural complexes and discharges.
During the site visit
Measure water level in each well. Record water-level measurements on the appropriate field form(s), and into the Ground-Water Site Inventory (GWSI) and Quality of Water Data (QWDATA) data bases.
Identify potential difficulties with the type of equipment and sample-collection methodology to be used. (Note that sampling plans will have to be modified accordingly.)
Update field folders. • Note site conditions that could affect the quality of data collected from that well. • Note change(s) in land use.
Verify well identification number and make sure that it is clearly and permanently labeled. • Check that identification corresponds with what is in the field folder and on site and location maps. • Correct any mistakes or uncertainty about well identification and well location.

Table 4-6. Example of ground-water site-inventory activities—*Continued*

During the site visit—*Continued*
Verify type of pump, well diameter, and use of holding tanks, pressure tanks, chemical treatments. • Check whether oil is floating on the water column in a well equipped with an oil-lubricated pump. • Make sure that the downhole treatment system is turned off before collecting water samples. • Determine if the intended sampling device is suitable for use.
Establish optimum pumping rate(s) for purging and sample collection and decide where to route excess discharge. • Adjust pumping rate to ensure adequate purging of the well without entrainment of atmospheric gases due to excessive drawdown. • Route water away from the well to prevent (1) creating muddy and slippery conditions and (2) damage to or defacement of the property to which you were granted access.
Check that well structure is intact. • Wells used for ground-water studies should be "sounded" annually to check whether depth to bottom corresponds with well-construction information or whether the well is filling with loose materials (U.S. Geological Survey, 1980; Lapham and others, 1997). A decrease in depth to bottom could indicate that the well casing is collapsing, or that there is a breach or corrosion of well screen or casing, or that the well is improperly designed to retain aquifer materials. • Borehole caliper and downhole-camera video logs can identify a damaged or broken well casing. A downhole camera can identify a plugged screen or accumulation of sediment in the well. • Aquifer tests, such as slug tests, can be used to check thehydraulic connection between the well and the aquifer. Aquifer tests, however, are generally beyond the scope of site reconnaissance. • The surface seal of a USGS monitoring well should be intact and the well should be capped. Concrete pad should be repaired if cracked or separated from outer casing. A tight-fitting well cap should have a small ventilation hole.
Check well access for sample-collection points. • Sample-collection points need to be near the wellhead, ahead of where water enters pressure tanks, holding tanks, or treatment systems. • At wells where an access point close to the well is not available, it might be possible to install a hose bibb or tap at the wellhead. Because it usually is not possible to control the pumping rate of a supply well, the field person may need to set up a hose-and-valve system to control the rate at which water is sampled and to reduce the likelihood of backflow of water stored in plumbing lines.
Check well access for water-level measurements. The construction of some supply wells makes water-level measurements difficult or impossible. • Although it is often possible to slip a weighted steel or electric well tape below the pump to get a water-level measurement, the pump can be damaged if the weight or tape becomes entangled in the pump. The weight should be attached so that it will snap off of the tape under stress. • Water levels can be estimated through the air line on some wells. • Sometimes field personnel are permitted to remove the pump from the well to get a measurement; however, pump removal can be difficult and time consuming, is potentially unsafe, and could damage the pump. • A note should be made in the well file if there is no access for a depth measurement.

NWIS files – USGS policy requires that specific information collected for each ground-water sampling site and event will be stored in one or more subsystems of NWIS (USGS Office of Water Quality (OWQ)/Office of Ground Water (OGW) Technical Memorandum 2006.01). In addition, paper documents (such as agreements between the well owner and the USGS for well use, access, or construction), field forms and logs, and any ancillary information that is collected are stored in well files and field folders (USGS Office of Ground Water Technical Memorandum 2003.03). Much of the information needed to set up files for existing wells can be obtained from well owners, drillers, records from state or local jurisdictions, and well-construction logs. Information needed to set up well files for new wells is compiled by field personnel as part of their responsibilities associated with well installation (Lapham and others, 1997).

- **NWIS –** Within the NWIS system, well information, ground-water levels, and water-quality data are stored in three subsystems: the Ground-Water Site Inventory (GWSI), Quality of Water Data (QWDATA), and the Automatic Data Processing System (ADAPS). Individual studies and USGS Water Science Center offices may have additional data-storage requirements.
  - GWSI primarily contains (1) descriptive information about the site and well, (2) construction information, and (3) noncontinuous water-level data. A GWSI site file (table 4-7) must be established for each well at which water-level and other data are collected (table 4-7) (Hoopes, 2004; USGS OWQ/OGW Technical Memorandum 2006.01). When creating or updating a GWSI site-file record, field personnel should fill in as much information as is available in addition to the required information. For example, the GUNIT (geologic unit) code provides important information for interpretation of ground-water data.
  - QWDATA contains (1) results of field and laboratory water-quality sample analyses and measurements, (2) non-continuous water-level data, and (3) other data related to water-quality samples or sample analyses (Gellenbeck, 2005). A subset of the information entered into GWSI is entered into QWDATA, as appropriate to meet the needs of the study (USGS OWQ/OGW Technical Memorandum 2006.01).
  - ADAPS contains continuous records of water levels and water quality (Bartholoma, 2003).

- **Field Folder –** The field folder contains information that is necessary or useful to have onsite during the field effort, and includes a well file for the well at which data will be collected (fig. 4-7).
  - — A well file is established for each well selected or installed for the study. The well file is the repository of the information compiled for the well, and it should contain documentation for site selection, well inventory, well installation, and sample collection.
  - — The field folder (fig. 4-8) is taken along on each site visit and includes site-location maps and a site sketch (fig. 4-9). Files taken to the field should not contain original data records.

To prepare location maps and site sketches:

1. Locate the ground-water site in the field on an aerial photograph, or a town plat/lot number map. Transfer the location of the site to a USGS 7.5 minute topographic quadrangle map.
2. Determine the ground-water site latitude and longitude to the nearest second using a USGS 7.5 minute latitude-longitude scale or a digitizer or Global Positioning System (GPS), and record the latitude and longitude accuracy as one second.
3. Prepare a detailed sketch map. Orient the ground-water site on the sketch map relative to north using a compass. The sketch map should contain enough detail so that the site can be found again by a person who has never visited it. All distances should be made in feet from permanent landmarks, such as buildings, bridges, culverts, road centerline, and road intersection.

RULE OF THUMB:

- **Before starting field work make sure the site file is established in NWIS.**
- **Keep field files current.**
- **After field work, update NWIS promptly.**

Table 4-7. Minimum information required for electronic storage of site and ground-water-quality data in the U.S. Geological Survey National Water Information System

[NWIS, National Water Information System; GWSI, Ground-Water Site Inventory; USGS, U.S. Geological Survey; QWDATA, Quality of Water Data]

Required information for creation of a ground-water site in NWIS[1,2] (GWSI)		
Data description	**Component (C) number for data entry into GWSI**	**Example (Description of code)**
Agency code	C4	USGS
Station Identification Number (Latitude/longitude/sequence no.)	C1	394224075340501
Station Name	C12	KE Be 61
Latitude	C9	394224
Longitude	C10	0753405
Country	C41	US
Lat/Long Accuracy	C11	S (seconds)
Lat/Long Method	C35	M (Map)
Lat/Long Datum	C36	NAD83
Time Zone	C813	EST
Daylight Savings Time Flag	C814	Y (Yes)
USGS Water Science Center/User	C6	24 (Maryland)
State	C7	10 (Delaware)
County	C8	003 (Sussex)
Station Type	C802	6 (Well)
Data Reliability	C3	C (Field Checked)
Site Type	C2	W (Well)
Use of site	C23	O (Observation)
Required information for storage of sample analyses in the water-quality subsystem (QWDATA)[1]		
Data description	**Alpha parameter code**	**Sample data (Description of code)**
Agency code	AGNCY	USGS
Station Identification Number	STAID	394224075340501
Sample Medium	MEDIM	6 (ground water)
Sample Type	STYPE	2 (blank sample)
Hydrologic (“Hydro”) Event	EVENT	9 (routine sample)
Hydrologic (“Hydro”) Condition	HSTAT	A (not determined)
Date (year/month/day)	DATES	20060909
Time (standard 24-hour clock time)	TIMES	1530 hrs
Analysis Status	ASTAT	H (initial entry)
Analysis Source	ASRCE	9 (USGS laboratory and field)

[1]Numerous additional data fields are available in GWSI and QWDATA that can be useful for data analysis or mandatory for meeting study objectives; for example, indicating whether an agency other than the U.S. Geological Survey collected the data.
[2]From GWSI Schedule Form 9-1904-A, revised June 2004, NWIS 4.4.

WELL-FILE CHECKLIST, Page 1 of 2

Project name and identification number:____

Latitude-longitude: ____________________________ Sequence number: ________________

Other site or well ID:_____________________ Station name: ___________________________

Indicate use of water/site: Public Supply Irrigation
Domestic Observation
Commercial Monitoring
Industrial Other ______________________________

Item in well file	Date item filed
Criteria for well selection or installation	____________
Station Analysis	____________
Station Description	____________
ADR (Automatic Data Recorder) Manuscript	____________
Ground-Water Site Inventory (GWSI) data entered into National Water Information System (NWIS)	____________
Paper copy of GWSI form (9-1904-A)	____________
Copies of agreement to complete activity (drilling, sampling, etc.) ____	____________
List agreements ____	____________
Copies of field forms and logs:	
Well-drilling record	____________
Driller's log	____________
Lithologic log: Cuttings	____________
Cores	____________
Aquifer tests: (list types)_______________________________________ ____	____________
Geophysical logs: (list types) ___________________________________ ____	____________
Well-construction record	____________
Well-development record	____________
Well-maintenance checks: (list types) __________________________ ____	____________
Well-location information:	
Latitude-longitude, datum, method of determination, and any changes	____________
Well-location map(s)	____________
Site-sketch map	____________
Written description of location	____________
Well-casing elevation (elevation, and method and date of determination)	____________
Photographs of well and vicinity (with measuring/sampling points identified)	____________
Land use/land cover form (Lapham and others, 1997)	____________

Figure 4-7. Example of a checklist for a well file.

WELL-FILE CHECKLIST, Page 2 of 2

Item in well file	Date item filed
Water-quality records for each sampling event (for example, purging, field measurements, field forms, sampling history) and copies of laboratory analyses requested	____________
	____________
	____________
	____________
	____________
Water-level measurements - current:	____________
	____________
	____________
Water-level measurements - historical:	____________
	____________
	____________
Record of well leveling (survey)	____________
Datum corrections	____________
Pumping schedule/history	____________
Type of pump in well and location of intake	____________

Description of measuring point for water levels: ____________________________________
____
____

Description of collection point for samples from

Supply wells ____

____

Monitoring wells____

Other information (for example, geologic unit, aquifer name): __________________________
____
____
____

Figure 4-7. Example of a checklist for a well file—*Continued.*

Field-folder checklist: ground-water quality		
✓	**Item**	**Comments**
	Forms (new forms and (or) examples of completed forms): • Permission forms—must be signed by proper authority. • Analytical Services Request form(s). • Ground-water field form and well-inventory form.	
	Equipment and supplies checklists.	
	Field-techniques manuals.	
	Safety information: • Nearest emergency facilities; home phone number of supervisor. • Diagram of where to park, placement of flags and cones. • Traffic conditions; location of power lines. • Environmental hazards such as weather and animals.	
	Site location and description: • Maps showing location and identification number of well(s). • Name of landowner, tenant, or other responsible party. • Site access instructions (call owner; get keys or tools needed for security gate, well house, well protective casing). • Photographs and land use/land cover form to document site conditions. • Well dimensions and construction logs.	
	Sampling schedule and instructions: • Laboratory analyses, codes, and bottle types. • Preservation requirements, including chilled samples. • Quality-control samples. • Location of sampler intake during sample collection. • Pumping rate for purging and sampling.	
	Purging instructions: • Number of well volumes. • Rate of pumping; containment and discharge of purge water. • Location of sampler intake during purging. • Field measurements and stability protocols. • Previous field-measurement and purge-volume records. • Discharge of purge water.	
	Water-level measurements: • Location of measuring point. • Previous records from well.	
	Ancillary information: • Geologic section(s). • Hydrologic section(s). • Borehole geophysical logs.	
	Shipping instructions: • Mailing labels; location of nearest post office or shipping agent. • Ice and holding time requirements.	

Figure 4-8. Checklist for contents of a field folder for ground-water sampling.

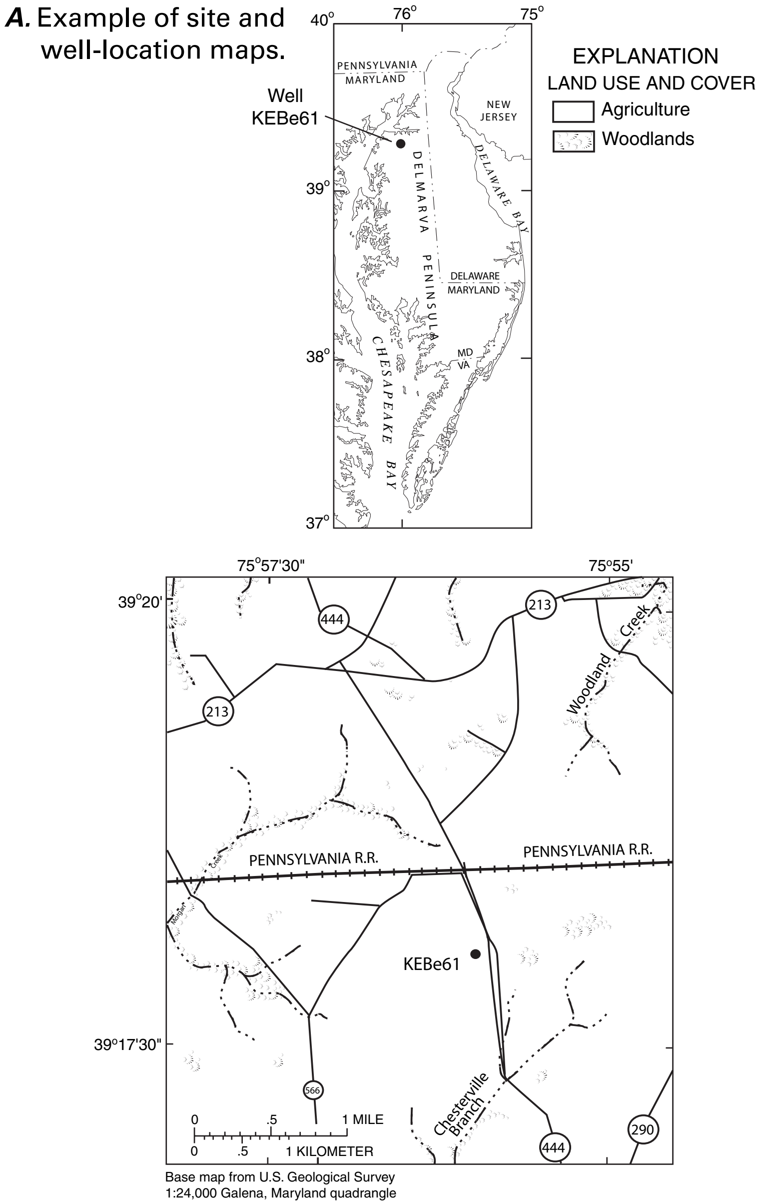
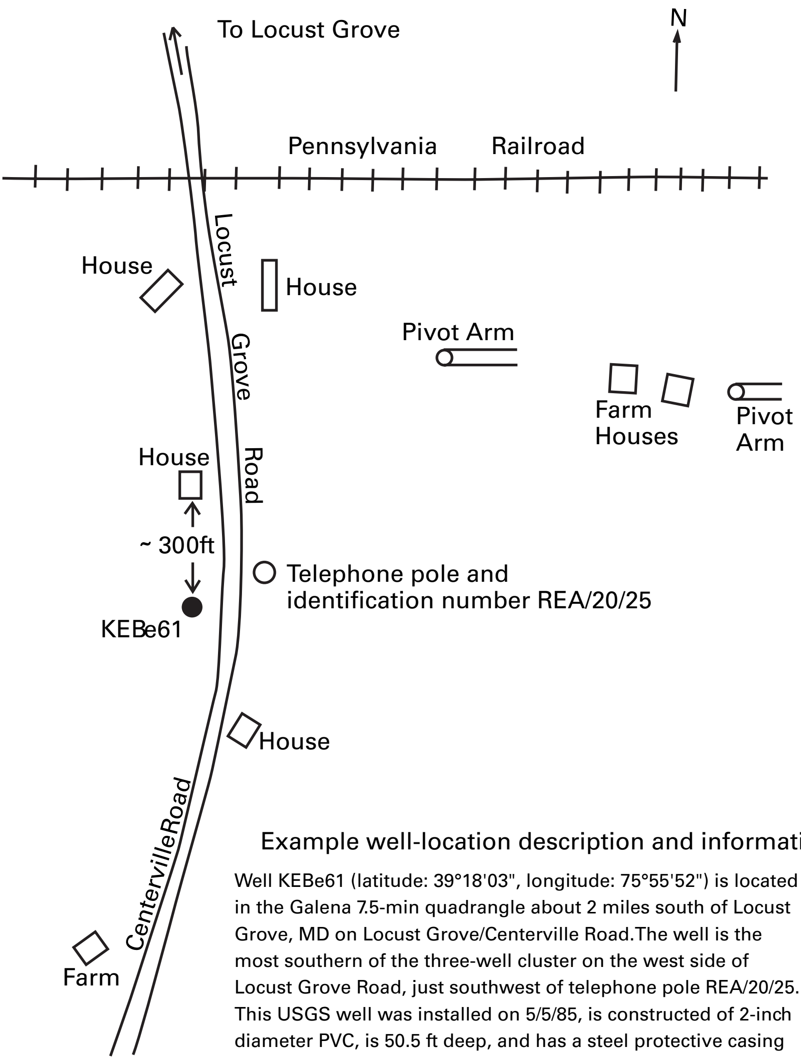


Figure 4-9. Example of (*A*) site- and well-location maps and (*B*) well-site sketch.

B. Example of well-site sketch (with well-site information).



Example well-location description and information:

Well KEBe61 (latitude: 39°18'03", longitude: 75°55'52") is located in the Galena 7.5-min quadrangle about 2 miles south of Locust Grove, MD on Locust Grove/Centerville Road.The well is the most southern of the three-well cluster on the west side of Locust Grove Road, just southwest of telephone pole REA/20/25. This USGS well was installed on 5/5/85, is constructed of 2-inch diameter PVC, is 50.5 ft deep, and has a steel protective casing with a USGS lock. Contact property owner at ( )___-____ one day before sampling.

Figure 4-9. Example of (*A*) site- and well-location maps and (*B*) well-site sketch—*Continued*.

4.2.2 CONSIDERATIONS FOR COLLECTING REPRESENTATIVE SAMPLES AT WELLS

The study team must ensure that the wells to be sampled will yield samples that accurately represent the water chemistry of the hydrogeologic system targeted for study. To help prevent data biases that could compromise study objectives, field personnel must be aware of how specific well characteristics and field activities can affect sample chemistry. These considerations are addressed as follows:

- Table 4-8 summarizes factors that can compromise sample integrity and general strategies for maintaining the integrity of ground-water samples. Table 4-9 lists considerations for selection or installation of wells at which water-quality will be monitored that relate to the quality or representativeness of the samples to be collected.
- Section 4.2.2.A discusses adverse effects on sample chemistry from introducing air and other fluids into the borehole during well construction, and the importance of monitoring the communication of the well with the aquifer for signs of deterioration.
- Section 4.2.2.B describes the effect of pumping rates, well yield, and aquifer heterogeneity and anisotropy on the sampling effort and how these factors can limit the types of sample analyses to be performed.
- Section 4.2.2.C focuses on the vulnerability of ground-water samples to contamination from atmospheric gases, standing fluids and bottom detritus in the borehole, and equipment use.

Some wells might not be suitable for water-quality monitoring. The ultimate decision as to when and if a well should be sampled rests with the study or program personnel and depends on the specific sampling and data-quality requirements of the study. Field personnel need to be alert to the conditions that might cause a change in the suitability of the well over time, whether because of well characteristics, land-use conditions, or other factors. **In general, avoid sampling:**

- Wells that cannot produce a continuously pumped sample or wells at which water-level recovery takes longer than 24 hours after being pumped.
- Wells at which purging will stir up bottom detritus that can bias analytical results. This often is the case in wells having 5 ft or less of water. Any reported interpretations of chemical analyses when sampling under such conditions must be clearly qualified and the well conditions documented.
- Wells at which field measurements have not met stabilization criteria (section 4.2.3), unless the study sampling and (or) quality-assurance plans provide for alternative protocols.
- Wells in which the water column within the sampling interval is in contact with and mixes with atmospheric gases, unless the analytes of concern will not be affected.
- Wells at which the water withdrawn must pass through holding tanks or chemical treatments.

Table 4-8. Considerations for maintaining the integrity of ground-water samples

Factors that can compromise sample integrity
• **Time.** Chemical and microbial reactions that affect target-analyte concentration can be rapid. • **Loss of pressure.** Pressure in ground water can be much greater than atmospheric pressure. As the sample is brought to land surface, depressurization of the sample can cause changes in sample chemistry. • **Leaching or sorption.** Chemical substances can be leached from or sorbed by the equipment that contacts the sample. • **Exposure to the atmosphere.** Atmospheric gases and particulates that enter the sample can affect the water chemistry. • **Temperature.** Ground-water temperature is often lower than the atmospheric temperature at land surface. As the sample is brought to land surface, an increase in temperature can increase chemical reaction rates and microbial activity and cause degassing.
Strategies to maintain sample integrity
• **Plan sampling at sites in a sequence that avoids contamination.** Start with pristine sites or those least contaminated or with lowest concentrations of dissolved solids or target analytes. End at the site with the highest concentrations of target analytes. • **Clean equipment.** Sample only with decontaminated equipment and quality assure the efficacy of the cleaning procedures (collect equipment blanks). • **Purge the well of standing water.** Purge the well to reduce artifacts from well installation or sampler deployment. If possible, pump at a rate that does not overly stress the aquifer, creating drawdown and mobilizing particulates. Protocols for purging and pumping rate can depend on well type and study objectives. • **Isolate the sample.** For example, use packers downhole and processing and preservation chambers at land surface. • **Avoid temperature changes.** Keep sample tubing as short as possible and shaded from direct sunlight. • **Avoid sample aeration.** Filter in-line; use thick, nonpermeable sample tubing; completely fill filtration assemblies and sample tubing with sample; fill sample bottles from bottom up to overflowing whenever appropriate; handle anoxic water under an inert gas atmosphere, if necessary (section 4.2.2.C). • **Collect quality-control samples.** Review the analytical results and adjust field procedures, if necessary, before the next sampling.

Table 4-9. Considerations for well selection and well installation

[Modified from Lapham and others, 1997]

Well location
• Location conforms to the study's network design for areal and depth distribution. • Land-use/land-cover characteristics, if relevant, are consistent with study objectives. • Site is accessible for equipment needed for well installation and sample collection. • Well elevation has been determined.
Hydrogeologic unit(s)
• Hydrogeologic unit(s) that contribute water to the well can be identified. • Depth and thickness of targeted hydrogeologic unit(s) are known or can be determined. • Yield of water is adequate for sampling (typically, a minimum of 1 gallon (3.785 liters) per minute).
Well records, description, design, materials, and structure
• Available records (for example, logs of well drilling, completion, and development) have sufficient information to meet the criteria established by the study. • Borehole or casing/screen diameter is adequate for equipment. • Depth to top and bottom of sample-collection (open or screened) interval is known (to determine area contributing water to well); well depth and other well-construction and well-development information is available. • Length of well screen is proportional to the vertical and areal scale of investigation. • Well has only one screened or open interval, if possible. (Packers can be used to isolate the interval of interest, but packers might not completely isolate zones in unconsolidated or highly fractured aquifers. If packers are used, materials of construction must be compatible with analytes to be studied.) • Top of well screen is several feet below mean annual low-water table to reduce chances of well going dry and to avoid sampling from unsaturated intervals. • Filter pack is of a reasonable length (a long interval compared with length of screened or open interval usually results in uncertainty as to location of the source of water to well). • Well-construction materials do not leach or sorb substances that could alter ambient target-analyte concentrations. • Well-structure integrity and communication with the aquifer are sound. (Checks include annual depth-to-bottom measurements, borehole caliper and downhole-camera video logs, and aquifer tests.)
Pump type, materials, performance, and location of sampler intake
• Supply wells have water-lubricated turbine pumps rather than oil-lubricated turbine pumps. (Avoid suction-lift, jet, or gas-contact pumps, especially for analytes affected by pressure changes, exposure to oxygen, or that partition to a gas phase.) • Pump and riser-pipe materials do not affect target-analyte concentrations. • Effects of pumping rate on measurements and analyses have been or will be evaluated. • Sampler intake is ahead of where water enters treatment systems, pressure tanks, or holding tanks.

4.2.2.A Well Construction and Structural Integrity

Lapham and others (1997) describe common well-drilling, well-completion, and well-development methods and the importance of checking the structural integrity of the well periodically. Study personnel should be aware of the effects that well installation and the potential failure of the well structure can have on the data being collected.

Effects of well construction

Well-drilling, well-completion, and well-development methods can have long-range effects on sample chemistry (Lapham and others, 1997). Field personnel should review the well-construction methods and materials used, in addition to the length and diameter of the well screen and casing and how the well was completed.

- Circulation in the borehole of air and fluids such as water, bentonite, and biochemical slurries can infiltrate the aquifer, thereby altering water chemistry or biochemistry. For example, studies indicate that samples collected for chlorofluorocarbon (CFC) and sulfur hexafluoride (SF_6) analyses at monitor wells drilled in fractured-rock aquifers using air-rotary methods can be biased for those analyses 12 months or longer after being drilled (L.N. Plummer, U.S. Geological Survey, written commun., 2006), although a three-well-volume purge protocol is used (section 4.2.3). Well development by air injection also is likely to bias CFC and SF_6 analyses and produce faulty interpretations with respect to ground-water ages (Shapiro, 2002). High-capacity, high-yielding, or frequently pumped supply wells are less likely to be affected. Claassen (1982) discusses how mud-rotary drilling, grouting, and other well-construction practices also can have a relatively long-lasting effect on major-ion compositions and chemical properties of ground water, and provides methods by which to analyze these effects.
- Mixing of waters with different quality can occur in wells with long or multiple screens because of well-bore flow. On the other hand, wells with short screens relative to the total thickness of an aquifer might be screened at intervals that miss major zones of interest, such as zones with high transmissivity or contamination.

Selection of the appropriate well design depends on study objectives. For example, if samples withdrawn from an unconfined aquifer will be analyzed for volatile organic compounds, dissolved gases, or trace metals, the top of the screened or open interval should be located far enough below the lowest anticipated position of the water table (3 ft (~1 m) or more) so that the screened interval will not be intersected by the water table during drawdown. The purpose of this design is to avoid gaseous diffusion into the sample from a partially saturated or open interval. On the other hand, the well might be designed specifically to screen across the water table to better assess the thickness of oil or other light non-aqueous phase liquids (LNAPL) floating on the water surface.

Deterioration of the well structure

The integrity of the well's construction can deteriorate or the well can "silt in" over time. The structural integrity of monitor wells and their hydraulic connection with the aquifer should be checked at least annually or as described below. Checking well integrity should be scheduled to occur during a nonsampling site visit, if possible. If the well integrity will be checked during a sampling field trip, do this only after completing sample collection to avoid stirring up particulates that could enter the sample and cause a bias in analysis of trace metals, polychlorobiphenyls (PCBs), or other analytes that tend to associate with particulate matter.

- ▶ Inspect the integrity of the surface casing and seal routinely when visiting the well.
- ▶ Inspect the subsurface casing (this can be done using a borehole televiewer).
- ▶ Note any changes in depth to the bottom of the well; this measurement should be made annually at wells with recurring water-level or water-quality data collection. In addition, the well should be tested for hydraulic connection to the aquifer every 3 to 5 years.
- ▶ Purge well water laden with particulates until turbidity values return to background or near-background levels; that is, the final turbidity value recorded after the well has been properly developed. Typically, the turbidity value measured at a properly constructed and developed well is about 10 turbidity units, although it is common for background turbidity in ground water to be 5 turbidity units (the threshold for visible turbidity). Turbidity values that cannot be improved to less than about 25 units after purging or well redevelopment can indicate failure of the well structure or that the well was improperly constructed. If possible, a different well should be selected or a new well installed.

4.2.2.B Well-Hydraulic and Aquifer Characteristics

Hydraulic characteristics of the well and the structural and material properties of the aquifer can impose specific constraints on the sampling effort and achieving results that can be interpreted within a defined measure of quality. These considerations affect the selection of the equipment and sampling methods to be used, and ultimately may result in determining that a well is unsuitable for the intended data-collection effort.

Pumping rate

The pumping-rate capability of a given well-and-pump system is related to well capacity. Compared with pumping rates at supply wells, pumping rates at domestic wells are low. Advantages and disadvantages associated with low- and high-capacity wells are described in Lapham and others (1997). When reviewing study objectives, consider the effect of the proposed pumping rate on the aquifer with respect to what the water quality of the samples to be collected will represent.

- Pumping a few tens of gallons per minute can induce substantial leakage from confining beds if drawdown is rapid (formation materials are low-yielding). By contrast, pumping at a rate of thousands of gallons per minute from high-yielding materials is not likely to induce such leakage.
- Pumping at a high rate can cause turbulence and thus turbidity in the water column, resulting in biased data.
- Pumping at a low rate (for example, 1 to 4 gal/min, or 3.8 to about 15 L/min) in deep wells might result in the sample taking several hours to reach land surface. A long residence time of water within the sample tubing may compromise sample integrity.

- Be aware that pumping at any rate draws water preferentially from the most transmissive intervals, whether in fractured rock or unconsolidated media. Since the wellbore has a much higher hydraulic conductivity than the formation, the sample collected represents a flux-weighted average of the various inflow locations and the location of the pump intake does not affect this result (A.M. Shapiro, U.S. Geological Survey, written commun., 2006; Gibs and others, 2000; Reilly and LeBlanc, 1998; Gibs and others, 1993; Reilly and Gibs, 1993).
- The rate of pumping during purging should remain constant and be maintained as the pumping rate for sample withdrawal and collection. Fluctuations in pumping rate affect sample quality (Gibs and others, 2000).

Low-yield wells

A yield of at least 1 gal (3.75 L) per minute without causing drawdown of about 2 ft or more below the top of the open or screened interval is recommended for adequate sampling at monitor wells with a diameter of 2 in. or greater (Lapham and others, 1997). Wells that yield less than 100 mL/min frequently incur substantial drawdown during well purging. **Low-yielding wells, especially those that exhibit slow recovery or are pumped dry, are not recommended for water-quality sampling.** Situations may occur, however, that necessitate use of such wells.

- Low yield may be a function of poor well construction. Try to improve the well yield by redeveloping the well. Mechanical surging methods commonly produce the best results and avoid introduction of contaminating fluids; however, such methods must be employed in a manner to avoid damage to the structure of the well (Lapham and others, 1997). Pumping or over-pumping methods usually are not as effective for increasing the well yield. It is advisable to consult with an experienced and reputable well driller
- When drawdown occurs across the open interval, contamination from atmospheric gases or other inputs can affect subsequent water chemistry; for example, VOC loss, contamination of ambient CFC and SF_6 concentrations, and increase in turbidity.

- Wells must be purged before sampling (see section 4.2.3). After purging, the water level in the well should recover to approximately 90 percent of its starting level before sampling should commence. In low-yield wells this can take several hours or longer, requiring potentially multi-day visits to complete a three-well-volume purge. The longer the recovery time, the lower the confidence that the sample to be collected can be considered representative of ambient aquifer water composition. The actual volume of well water purged needs to be documented if it is less than the standard three-volume protocol.

RULE OF THUMB:

Do not sample wells at which recovery of water level after purging to 90 percent exceeds 24 hours.

- Consider whether packers can be used to seal off the interval to be sampled; in this case, only the isolated interval needs to be purged. This assumes that the interval selected is sufficiently transmissive to yield the volume needed of formation water. **CAUTION:** installing packers within a well screen can result in drawing in water from above or (and) below the packed-off interval through the filter pack in the annular space.

- Weigh several factors when selecting the sampler to withdraw water from a low-yield well. If possible use a low-volume submersible pump (for example, a Bennett pump).
  - — Bailers may stir up particulate matter and compromise specific analyses of interest.
  - — Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in loss of volatile analytes.
  - — Operating variable-speed, electrical submersible pumps at low flow rates may result in heating of the sample as it flows around and through the pump; this also can result in sample degassing and VOC loss, in addition to changes in other temperature-sensitive analytes.

Aquifer media with defined paths of preferential flow

In order to make a relevant interpretation of the sample chemistry, it is necessary to take into account the aquifer interval or intervals that yield substantial contributions of water to the well and understand the hydraulic conditions within the well that result from (a) ambient flow in the aquifer to the well, and (b) the conditions induced by sampling (Shapiro, 2002).

- **Regardless of the pumping rate or location of the pump intake**, water will be withdrawn first from the borehole and only later in time from the aquifer. The heterogeneity and anisotropy within the (consolidated or unconsolidated) aquifer interval being sampled dictates the paths of permeability through which formation water enters the well.

- **Flow dynamics within the well must be understood to determine if and when the water being withdrawn represents fresh formation water.** Differences in head (from contributing paths of flow within the aquifer) and differences in solution density from these contributing areas of flow will result in flow within the borehole.

4.2.2.C Vulnerability of Ground-Water Samples to Contamination

Because guidance cannot account for every potential threat to data quality, the responsibility lies with the field personnel to (a) be aware of the factors that can compromise the quality of the ground-water samples collected (table 4-8), and (b) use appropriate techniques and strategies to minimize and account for bias in the resulting data (section 4.3). The most common sources of sample contamination result from improperly cleaned equipment; contact or random particulate input from the atmosphere; and sample-water contact with hands, fumes, or other extraneous matter during sample-handling activities (Horowitz and others, 1994).

- Implement "good field practices" and collect quality-control samples (section 4.0).
- Use Clean Hands/Dirty Hands sampling techniques (table 4-3).
- Use equipment-selection and equipment-cleaning procedures that are described in NFM 2 and NFM 3, respectively.
- Withdraw sample water in a manner that avoids turbulence, contact with the atmosphere, and changes in temperature and pressure.
- Avoid sampling at wells that have less than 5 ft of water column, to prevent inclusion of detritus from the bottom of the well.
- As a rule, collect, process, and preserve samples within clean, enclosed chambers.
- Review the results of equipment blanks, field blanks, and other quality-control (QC) information well in advance of sampling. Use this information to adjust sampling plans and procedures, or to otherwise prepare for field work.

Standing borehole water

The chemical composition of standing water in a borehole is affected by well-construction practices, as described above, by contact with the initial and overlying air within the borehole, by geochemical and biochemical processes occurring in the borehole water, and by the vertical as well as horizontal borehole flow. Borehole flow is partially a function of hydraulic head differences within zones of preferential flow in the aquifer; consequently, water can move up or down vertically as well as into and out of the aquifer horizontally (Shapiro, 2002).

Formation water that is stored in a filter (gravel) pack within the annular space between the well casing (screen) and aquifer is not necessarily representative of formation-water chemistry, but can take on the mineral signature of gravel materials and can cause a change in pH values. Assuming that the well has been appropriately developed, the well also should be purged of standing water each time before samples are withdrawn (see section 4.2.3).

Atmospheric and dissolved gases

Exposure of anoxic or suboxic samples to the atmosphere can increase dissolved-oxygen (DO) concentrations to a well above ambient concentrations, causing bias not only in the DO data but also in the results of analyses for particulate and dissolved metals, sulfide, VOCs, CFCs, SF_6, microorganisms, and measurements of pH and alkalinity. Minimize or isolate the sample from atmospheric contact, using the following procedures, as appropriate.

- If pumping, only use pumps that can deliver a smooth, nonturbulent flow in-line to the sample collection/processing chamber (NFM 2.1.2). The same pumping technique applies for making field-measurement determinations (NFM 6.2), whether pumping while using a multi-parameter instrument for in situ measurements or to deliver the sample to a flowthrough chamber.

- Avoid sampling at monitor wells in which the sampler intake is drawing in water that has mixed with the overlying air column. If sampling at such wells cannot be avoided, samples should not be collected for analysis of dissolved gases such as VOCs, CFCs, and SF_6. The accuracy of trace-element data from such samples also may be in question. Check the list of analytes and data-quality requirements to determine if samples of the appropriate quality can be acquired.

- Use transparent sample-delivery tubing. Avoid entraining bubbles in the tubing by filling it to capacity; if bubbles form, tap the tubing with a blunt object to dislodge them and move them out.

- Fill sample containers within a processing chamber.
  - — An effective bottle-filling method is to insert the discharge end of clean sample tubing to the bottom of the bottle so that the sample fills the container from the bottom up to overflowing. Cap the bottle quickly. This method is not practical for every sample type.
  - — Atmospheric oxygen can be completely removed from the processing chamber (or glove box) by filling it with a clean, inert gas, especially one that is heavier than air, such as argon. Alternatively, good results have been documented by passing inert gas over the sample bottle opening while filling the bottle or by filling the bottle (and capsule filter, if used) with the inert gas beforehand.

To fill a chamber with inert gas:

1. Insert a desiccant pack in-line between the gas tank and the processing chamber.
2. If using a processing chamber, add a "T" fitting at the top to secure the small-diameter gas delivery hose, which is then inserted through the chamber cover.
3. Seal the chamber cover closed by twisting and tightly clipping it or using some other sealing method.
4. Start the flow of inert gas into the chamber.
5. Cut slits through the top (this is not needed if using a glove box) to allow access with gloved hands. Note that the entry of gas drives air out of the chamber through the slits.

Ground-water samples with ambient concentrations of dissolved gases (for example, methane) should be collected so as to avoid degassing. Degassing can occur from an increase in water temperature as the sample is brought to the surface, or because of leaks in the sampling and pressure system.

- ▶ Effervescent waters or samples collected for dissolved-gas analysis should use a Kemmerer or other sampling device designed to maintain ambient pressure. Collect CFCs and SF_6 samples using the procedures described on the USGS Reston Chlorofluorocarbon website, http://water.usgs.gov/lab/ (accessed July, 2006).
- ▶ Check that all equipment connections and fittings are airtight.

Use of sampling equipment

The type of equipment used for well purging and sample withdrawal can affect the quality of the sample and how the data are interpreted. Samples of ground water from monitor wells generally arewithdrawn using a submersible pump, a peristaltic or valveless metering pump, or a point sampler such as a bailer, thief sampler, or syringe; supply-well pumps generally are permanently installed and should not be removed unless absolutely necessary and with the owner's permission (NFM 2). Equipment to be used for sampling – the materials of construction and the manner of operation – must be checked against the list of target analytes and the characteristics of the well in order to determine whether the equipment is appropriate to meet study requirements. Select and prepare equipment using the guidelines and protocols described in NFM 2, 3, and 6[14] and shown on figure 4-10.

- ▶ The sample-wetted parts of the equipment must be constructed of materials that will not contaminate the sample with respect to target analytes (NFM 2). Collect an equipment blank before field activities begin to test the suitability of the equipment for its intended use.

[14]NFM 2, "Equipment selection for water sampling;" NFM 3, "Equipment cleaning for water sampling;" NFM 6, "Field measurements."

- All sampling equipment must be cleaned and the efficacy of the cleaning or decontamination procedures should be confirmed with analyses from quality-control samples (NFM 3). Document in field notes the cleaning and quality-assurance procedures used, along with the analytical results for equipment-blank samples collected to test cleaning procedures.
- A flow-splitting manifold (fig. 4-10) constructed of noncontaminating materials is recommended for directing the pumped-sample flow to the point of sample collection (usually a sample-collection or sample–processing chamber).
- When setting up a pump system that requires a hydrocarbon-fueled generator, take note of the wind direction and locate the generator downwind from the sampling operation.
- Pump tubing should be kept as short as possible (to avoid changes in sample temperature) and should extend directly into a processing chamber or glove box to avoid sample contamination from the atmosphere. Set up sample chambers before beginning sample collection (a flowthrough chamber, if used for field measurements (NFM 6); and processing and preservation chambers for sample collection and filtration, and preservation, respectively).
- The sampling device should be conditioned with the well water before being used to collect samples.

To condition or field rinse a ground-water sampler:

1. Wearing disposable gloves, gently lower the sampler through the water column in the well to the selected sampling depth interval. Take care to minimize disturbance in the water column and minimize disturbance of sediments at the bottom of the well.
   - If using a pump sampler, field rinsing is accomplished with well purging, provided that the well will be purged with the same equipment to be used for sample withdrawal. Water should be pumped through the sample tubing to achieve the equivalent volume of three equipment rinses.
   - If using a point sampler, fill the sampler partially with the water to be sampled; shake or swirl it to cover all interior parts of the sampler. Drain the rinse water through the nozzle or bottom-emptying device. Repeat this procedure three times.
2. Discard or contain the well-water rinsate (including purge water) as appropriate, to comply with waste-disposal regulations; this is especially critical if the water is known or suspected to contain toxic levels of chemical substances.

Well-bottom detritus

Incorporating sediment or other detritus from the bottom of the well into the sample can result in data that do not represent the composition of native aquifer water. To avoid this:

- ▶ Lower the pump or other sampler slowly and smoothly to the desired point of sample intake; that is, without creating turbulence and without stirring up bottom detritus.
- ▶ Keep the sampler intake far enough above the bottom of the well to avoid drawing in bottom detritus.
- ▶ Maintain a pumping rate that is not so high as to draw in bottom detritus.

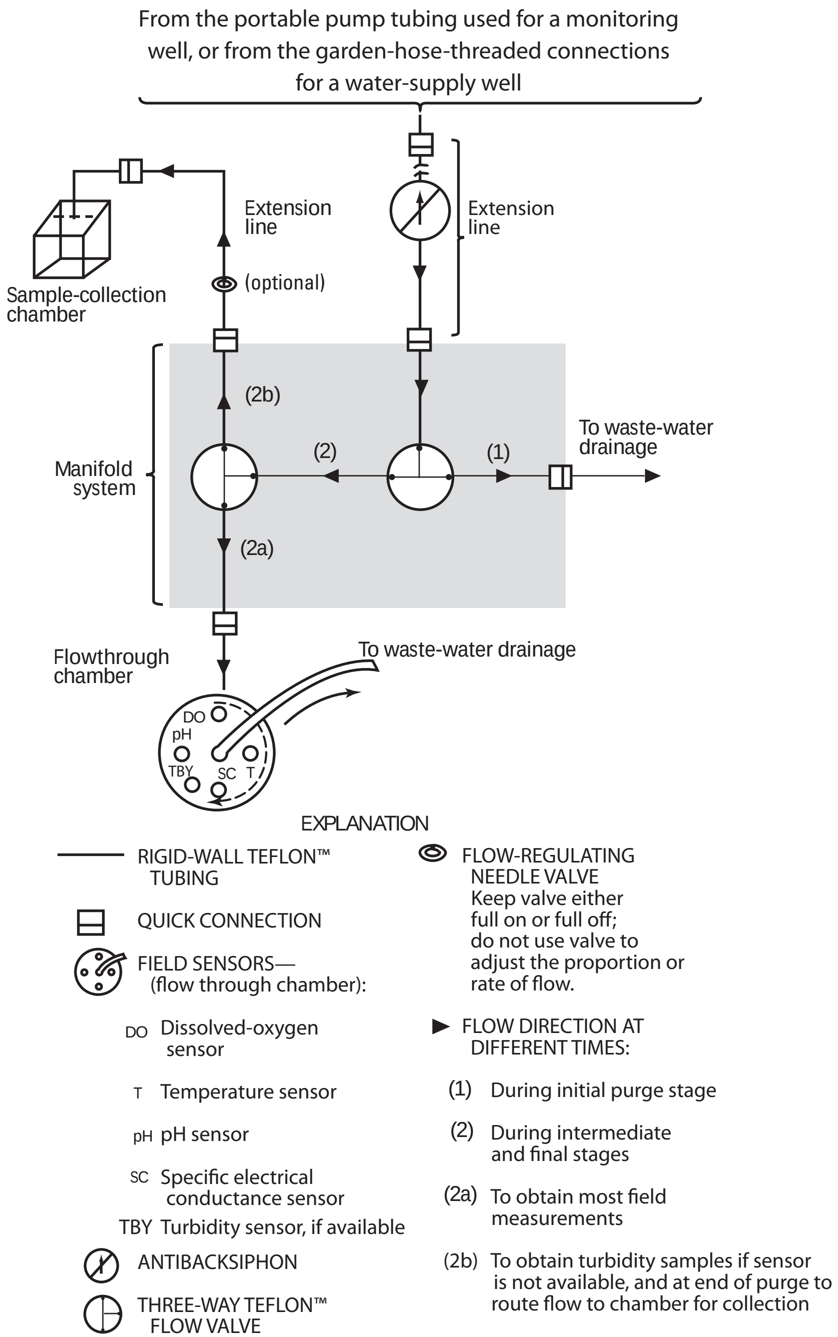


Figure 4-10. Example of a manifold used for well purging and sample collection (modified from Koterba and others, 1995).

WELL PURGING 4.2.3

Well purging removes standing water from the borehole. The purpose of purging is to reduce chemical and biochemical artifacts caused by the materials and practices used for well installation, well construction, and well development, and by reactions occurring within an open borehole or annular space between a well casing and borehole wall.[15] Purging also serves to condition the sampling equipment with well water. The purging process forms a continuum with that of sample withdrawal. Sample withdrawal is the process by which sample water is transported for collection and processing, after the well has been purged.

Standard purge procedure 4.2.3.A

As a rule of thumb, the standard USGS purge procedure removes three or more well volumes of standing water while monitoring the water level and the stabilization of routine field measurements as a function of time, pumping rate, and the volume of water being removed (figs. 4-11 and 4-12). Routine field meaurements include pH, temperature, specific electrical conductance, dissolved oxygen, and turbidity. Inherent in the purge procedure is an assumption that stabilization of field properties indicates that the discharge water represents ambient formation water. Field personnel should examine this assumption for each well, using their knowledge of the well and aquifer hydraulics. Review of the purging history, including physical and chemical data monitored, can save time and help determine how the well should be purged.

[15]Passive sampling methods may not require purging of the well prior to sample collection (Vroblesky, 2001; Powell and Puls, 1993; and Ronen and others, 1987).

- When calculating a purge volume for a cased well:
  - Include an estimate for the volume of water stored in the annular space between the casing and borehole wall, using knowledge of the borehole diameter. It is mandatory to evacuate at least one borehole volume (that is, casing volume plus that of the annular space), whether that space has been backfilled with formation materials or with a gravel pack.
  - Make the calculation of casing volume using the height of the water column to the bottom of the well, instead of the water column height to the top of the screen.

- The number of well volumes to be evacuated relies on confirming the time over which field measurements stabilize, using knowledge of the well and aquifer hydraulics.
  - To the extent practical, field personnel should apply an understanding of the borehole and aquifer hydraulics for the well to determine when the water being withdrawn from the borehole will likely be dominated by formation water (Shapiro, 2002; Claassen, 1982).
  - Values for field properties are recorded sequentially and at regular time intervals. The frequency of these measurements depends on the purging rate, which in turn is a function of well depth and diameter, and aquifer transmissivity. Field-property stabilization should be plotted as a function of a logarithmic time scale rather than a linear time scale, to best determine the point at which the contribution of aquifer water dominates pump discharge (see Shapiro, 2002). Field-measurement procedures are detailed in NFM 6.
- Purging should not cause substantial drawdown in monitor or supply wells when pumping at a rate of at least 1gal (3.75 L) per minute. Ideally, drawdown will be at a steady state, with the water level remaining above the top of the open or screened interval.
- Use of a borehole packer system or well liner is recommended for wells in fractured or low-yield media, to isolate zones of highest hydraulic conductivity or of particular interest. Transducers should be installed above and below the packers to monitor head differences.

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	Well casing diameter (D) (in inches)	Gallons per foot of casing
Well volume = $V = 0.0408\ HD^2$ **=___ gallons,** where V is volume of water in the well, in gallons, D is inside diameter of well, in inches, and H is height of water column, in feet **Purge volume = (*n*)(*V*) = ______ gallons,** where n is number of well volumes to be removed during purging ***Q*** **= estimated pumping rate = ______ gallons per minute** **Approximate purge time = (purge volume)/*Q* = ______ minutes**	1.0 1.5 2.0 3.0 4.0 4.5 5.0 6.0 8.0 10.0 12.0 24.0 36.0	0.04 .09 .16 .37 .65 .83 1.02 1.47 2.61 4.08 5.88 23.50 52.90

Explanation:

Well volume: Volume of water in a borehole or cased well.

Well volumes: For cased wells, the actual number of well volumes should account for evacuation of at least one volume of water stored in the annular space between the casing and borehole wall. This can be estimated from knowledge of the drilled well diameter.

Approximate purge time: Actual purge time depends also on field-measurement stabilization (use fig. 4-12).

Figure 4-11. Estimation of purge volume and purge time.

RECORD OF WELL PURGING

Date: ___________________ By: ____

SITE ID __________________________ STATION NAME ____

HEIGHT OF WATER COLUMN___________________ DEPTH OF WELL_________________________

PUMP INTAKE (ft or m below MP): Start__________ End _______________________________________

WELL-PURGING METHOD AND PUMP TYPE (describe):______________________________________

____

TIME	WATER LEVEL below *MP LS	DRAW-DOWN	TEMPER-ATURE	CONDUC-TIVITY	pH	DISSOLVED OXYGEN	TURBID-ITY	APPROX. PUMPING RATE
HR:MIN	*ft or m	*ft or m	°Celsius	µS/cm	standard units	mg/L	**	*gpm or L/min

*Circle the unit used; MP, measuring point; LS, land surface; HR:MIN, hour and minutes; ft, feet; m, meter; µS/cm, microsiemens per centimeter at 25°C; mg/L, miligrams per liter; gpm, gallons per minute; L/min, liters per minute.

**Select the appropriate turbidity unit from http://water.usgs.gov/owq/turbidity_codes.xls.

Well volume = $V = 0.0408\ HD^2$ = ____ gallons. **Purge volume** = $(n)(V)$ = ____ gallons.

V = volume of water in well, in gallons; D = inside well diameter, in inches; H = height of water column, in feet; n = number of well volumes to purge.

Well volume is 0.16 gallons per foot for a 2-in. casing diameter.

FIELD MEASUREMENT	STABILITY CRITERIA[1]
pH	± 0.1 standard units
Temperature (T) (in degrees Celsius)	± 0.2°C (thermistor thermometer) ± 0.5°C (liquid-in-glass thermometer)
Specific electrical conductance (SC)	± 5%, for SC ≤ 100 µS/cm ± 3%, for SC > 100 µS/cm
Dissolved-oxygen concentration (DO)	± 0.3 mg/L
Turbidity (TBY)[2]	± 10%, for turbidity < 100

[1]Allowable variation between 5 or more sequential field-measurement values.

[2]Select appropriate TBY unit from http://water.usgs.gov/owq/turbidity_codes.xls

Figure 4-12. Example of a field log for well purging.

Exceptions to the Standard Purge Procedure 4.2.3.B

Site characteristics, well characteristics, or study objectives could require modification of the standard purge procedure by changing the number of well volumes removed or by changing or adding types of field measurements and analyses. **Any modification to the standard well-purging procedure must be documented.** When standard purge volumes cannot be removed, (1) sufficient water must be withdrawn from the well to evacuate at least one borehole volume and to field rinse the sampler and sample tubing—alternatively, flush the pump and tubing system with the equivalent of three tubing volumes of DIW and purge the DIW from the tubing with clean nitrogen gas; and (2) field measurements should be determined before collecting samples, if possible. A lesser purge volume or other procedures may be modified, for example, when:

- A supply well to be sampled is being pumped continuously or daily at regular intervals and long enough to have removed three casing volumes of water—go directly to monitoring field properties.
- The sample-collection interval is sealed with packers (the interval to be sampled should be purged of three volumes).
- Water-level recovery from drawdown to approximately 90 percent of the original volume in the well cannot be achieved within a reasonable timeframe (not to exceed 24 hours; see the previous discussion on low-yield wells).
- The study will customize the protocol for field-determined properties or constituent analyses to address specific study objectives; however, the routine suite of field-measurement values should be determined.

TECHNICAL NOTE: Target or indicator analytes may be added to the purge criteria to address study objectives. The analysis can be performed onsite using portable analytical equipment or a mobile laboratory. The acceptable variability in analyte measurements to define stabilization and minimum number of readings is defined by the study (ASTM International, 2005).

- One or more field measurement keeps drifting, and sampling at that well cannot be avoided—NFM 6 provides suggestions for poor field-measurement stabilization, including extending the purge time and purge volume. Field personnel must make a decision based on their understanding of study objectives whether to extend purge time. Such decisions should be documented in field notes.
- Use of low-flow purging techniques is a stipulated study requirement: for a detailed description of the low-flow purge technique, refer to ASTM standard procedure D6452-99 (ASTM International, 2005).

TECHNICAL NOTE: Low-flow purging procedures are designed to minimize the volume of purge water and disturbance of the water column and maximize the contribution of formation water from a given interval of interest (Puls and Barcelona, 1996; Unwin and Huis, 1983). Minimizing purge volume is especially useful when regulating authorities mandate containment of purge water.

Low-flow purging is based on the theory that water moving through the well intake is representative of formation water surrounding the intake, and assumes that pumping at a low flow rate isolates the column of standing water so that only formation water is drawn into the intake. The typical flow rates for this method are on the order of 0.1 to 0.5 L/min; however, in formations of coarse-grained materials the flow rate may be as high as 1 L/min (ASTM International, 2005).

Select a low-flow purge-and-sampling technique with caution and with an understanding of aquifer and well hydraulics. The assumption should not be made that water withdrawn using a low-flow procedure represents ambient aquifer water at the targeted (intake) interval (Varljen and others, 2006), because the conductivity of well-bore flow within the specified interval is greater than that of the aquifer (Shapiro, 2002). Even where well-bore flow does not occur, aquifer heterogeneity over the length of the specified interval results in water being drawn preferentially through zones of highest permeability.

STEPS FOR SAMPLING AT WELLS 4.2.4

Develop a systematic agenda well in advance of the field effort that follows the sampling plan and quality-assurance protocols. Offsite preparations in addition to the steps needed to carry out onsite activities need to be included in planning for field work. Review the requirements and recommendations for site inventory (reconnaissance) and site file setup (section 4.2.1) .

Field-trip preparations. Adequate time must be scheduled to plan sampling activities, review data requirements, and make field-trip preparations. Prepare a checklist of equipment and supplies that will be needed, and order what is needed well before the field effort (fig. 4-13). Refer to NFM 2, Section 2.4, for lists of equipment and supplies commonly used for ground-water field activities. Review electronic and paper site files and make sure that they are kept up to date.

Before selecting and implementing purging methods, review table 4-8 to determine how maintaining sample integrity applies to the study and site.

- ▶ Consider whether modifications of standard USGS methods might be needed to address issues specific to the field site or program or study objectives. Document any deviation from the standard protocols.
- ▶ Review the types of quality-control (QC) samples planned for the study. Certain types of blank samples are required for all USGS studies. Review the most recent analyses of blank samples collected through the equipment to be used for sampling before field work begins.
- ▶ Determine if water level and well yield are sufficient to produce a representative sample.
- ▶ Decide how to determine or constrain the interval(s) from which the sample should be collected. Consider whether packers will be used and whether screen lengths are sufficiently short or long to meet the sampling objective. Determine the major sources of flow contribution to the well, if sampling in fractured or anisotropic formation materials.

Before leaving for the field site, review reconnaissance notes from the site inventory (table 4-6), and determine the number and types of environmental and QC samples to be collected (Appendix A4-C).

- Prepare the field forms that will be needed (for example, water-level, purging, field-measurement, analytical services request, and chain-of-custody forms). Fill out as much information as possible, including the equipment to be used and numbers and types of samples to be collected.

- Check equipment requirements (NFM 2). When assembling the equipment, test that equipment is in good working condition. Take backup equipment, as appropriate.

  — **Organic-compound samples.** Use fluorocarbon polymer (Teflon), glass, or metal for equipment components that will be in contact with samples to be analyzed for organic compounds. **Exception:** if collecting CFC samples, do not use Teflon sampler components or Teflon tubing (NFM 5).

  — **Inorganic-constituent samples.** Use fluorocarbon polymer or other relatively inert and uncolored plastics or glass for any equipment components that will be in contact with samples to be analyzed for inorganic constituents. Do not use metal or rubber components for trace-element sampling. Stainless-steel sheathed pumps are generally acceptable, but can leach low concentrations of chromium, molybdenum, nickel, and vanadium to the sample. **Collect an equipment blank to be analyzed before sampling begins, to demonstrate the acceptability of the data to be collected.**

- Set up a clean workspace (usually in the water-quality field vehicle) and the sample-processing and -preservation chambers. Place the filter unit and other necessary supplies for sample collection and processing into the processing chamber. **The generator and gas tanks must not be stored or transported in the water-quality field vehicle.**

Plan ahead. Take adequate time for site recon, and to prepare sampling plans, order supplies, test equipment, and get the training needed.

✓	Checklist for ground-water site setup and well-sampling preparations[1]
	Antibacksiphon device (one-way or check valve)
	Chemical reagents (for sample preservation and field analyses) and ice
	Deionized water and blank water
	Disposable, powderless, laboratory-grade gloves
	Equipment cleaning, decontamination, and disinfectant supplies
	Field forms (for example, ground-water-quality, water-level, and chain-of-custody forms) - electronic or paper; indelible ballpoint pen (black or blue ink)
	Field manual, sampling and quality-control plan(s)
	Filtration units and supplies
	Flow-regulating valve (needle valve or pinch clamps)
	Flow-splitting valve(s) for manifold system
	Flowthrough cell or chamber and field-measurement instrument(s) (single parameter or multiparameter); standard and buffer solutions; Kimwipes (see NFM 6)
	Keys (for locked facilities)
	Microbiota sampling supplies (see NFM 7)
	Photoionization detector (PID or sniffer)
	Sample processing and preservation chambers in which samples are bottled and treated, respectively, and associated supplies
	Safety equipment
	Sample containers (precleaned)
	Sampling device(s) (precleaned, portable equipment or other, as appropriate) and power supply (if needed); spare batteries
	Sample tubing (precleaned, several lengths)
	Shipping containers and supplies
	Stopwatch and calibrated bucket to measure pumping rate
	Tarp or plastic sheeting to place around well
	Threaded fittings, male/female, such as hose-type connectors (precleaned)
	Tools (such as wrenches to remove well cap)
	Tubing to direct waste discharge offsite or into sample container
	Water-level measurement equipment

[1]See NFM 2.4 for more detailed examples of equipment and supply checklists for sampling.

Figure 4-13. Example of checklist of equipment and supplies to prepare for sampling ground water at wells.

Steps for sampling. The standard USGS procedure for collecting ground-water samples consists of the following six basic steps and the activities needed to carry them out. The procedures needed for supply wells differ somewhat from those used for monitor wells. Steps 1 through 4 are detailed in this section. Steps 5 and 6 are described in NFM 5 ("Processing of Water Samples") and NFM 3 ("Cleaning of Equipment for Water Sampling"), respectively.

Step 1. Implement safety precautions and site preparations

Act with common sense. Be aware of existing and impending environmental conditions and hazards. Field personnel must be familiar with the guidance and protocols provided in NFM 9, "Safety in Field Activities." Organized and orderly procedures for setting up a site for sampling should be routine and helps to prevent mistakes that could compromise personnel safety as well as sample integrity.

Step 2. Measure water level

Procedures for water-level measurement can differ for supply wells and monitor wells. Detailed procedures for various methods of measuring water levels are documented by the U.S. Geological Survey (1980, p. 2-8), and additional information can be obtained from the USGS Office of Ground Water (http://water.usgs.gov/ogw). Refer to Appendix A4-B for a summary of water-level-measurement methods.

- Procedures and equipment for water-level measurement can differ, depending on the type, construction, and design of a well.
- Clean well tapes after each use at a well as described in NFM 3.3.8. Document in field notes if oil is floating on the water table. Review equipment-cleaning and sample-collection strategies and revise as needed if oil is present, to prevent contamination of samples. A dual-phase sonde can be used to determine the thickness of the oil layer, as well as the depth to water.
- Record discrete water-level measurements on field forms and in GWSI (USGS Office of Water Quality Technical Memorandum 2006.01).

Step 3. Purge the well and monitor field measurements

As discussed in Section 4.2.3, purging the well of standing water is generally required to ensure that the sample water will be withdrawn directly from the aquifer. Exceptions to the well-purging protocol may apply more commonly to water-supply wells, although exceptions for some monitor wells also have been described in the previous section. Regardless of the purge procedure followed, enough water must be withdrawn from the well to field rinse sampling equipment and to make measurements of field properties (field measurements). Purging and field-measurement information must be recorded, either on electronic or paper field forms (fig. 4-12). Specific guidance for use of field-measurement instruments is described in detail in NFM 6.

Step 4. Withdraw the sample

As a rule, pumping is the preferred method for withdrawal of ground-water samples. In this case, purging and sample withdrawal form a continuous process. Field measurements are monitored during purging with sample collection following immediately after final field measurements have been recorded. Equipment is selected that channels flow in-line to a field-measurement chamber and then, without stopping, to a sample collection/processing chamber; the sample is never exposed to the atmosphere during this process (fig. 4-10).

Depending on field conditions and study objectives, samples may be withdrawn using a thief-type sampler. Lower and raise the sampler smoothly at a constant rate, keeping the suspension line clean and off the ground. A bailer or other thief-type sampler generally is not recommended for trace-element or volatile organic compound (VOC) sampling. Bailing can mobilize particulates and, unless designed for VOC sampling, can allow VOCs to escape.

- ▶ Measurements at a monitoring well
  - — The standard purging procedure usually is appropriate (section 4.2.3.A). Exceptions to the standard purging procedure are described in section 4.2.3.B.
  - — Either a downhole or a flowthrough-chamber system can be used for field measurements (NFM 6). If samples will be collected, use the flowthrough chamber instead of the downhole system in order to avoid bias of chemical analyses from sample contact with downhole instruments.

- Measurements at a supply well
  - — The standard purging procedure may not be appropriate (see section 4.2.3.B).
  - — Identify well-construction materials and any equipment permanently installed in the well (such as a pump) that can affect the logistics and quality of the field measurement or sample.
  - — Use a flowthrough-chamber type of field-measurement system (NFM 6).
  - — Connect the field-measurement system to the wellhead at a point before the sample would pass through holding tanks, backflow pressure tanks, flow meters, or chemical treatment systems.

If more than one well will be sampled during a field trip, each site and (or) a field vehicle must be set up for onsite cleaning of the sampling equipment. Field personnel should design the most efficient field-cleaning system, appropriate for the sites to be sampled and in accordance with the equipment-cleaning guidelines described in NFM 3.

Step 5. Process the sample

Sample processing involves, in part, sample filtration, sample collection into appropriate containers, and sample preservation. Standard USGS procedures for sample processing are described in general and according to analyte type in NFM 5.

Step 6. Clean the equipment

Standard USGS procedures for cleaning (or decontamination) and QC of specific types of equipment used for collecting and processing organic and inorganic analytes are detailed in NFM 3. Field personnel should design the most efficient field-cleaning system, appropriate for the sites to be sampled and in accordance with wastewater disposal regulations.

Practice safe sampling.

Supply Wells 4.2.4.A

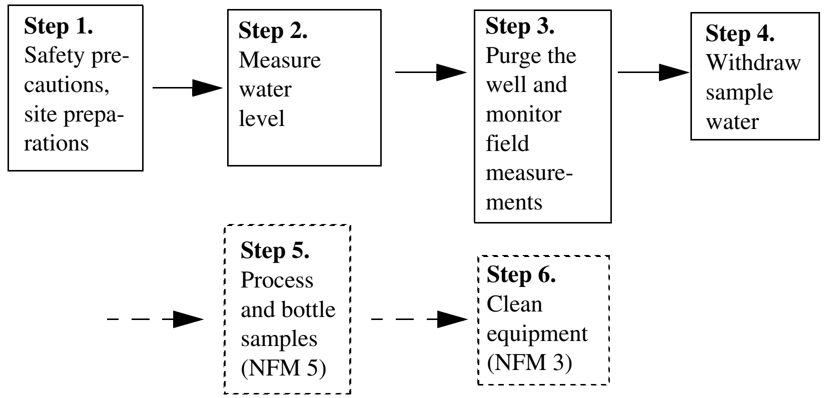
Collection of samples from water-supply wells with permanently installed pumps requires specific considerations, preparations, and precautions. Refer to NFM 9 for safety precautions. Field personnel should be aware of the potential sources of contamination to samples withdrawn from supply wells (table 4-10).

- Do not sample the well if it is not possible to bypass any holding tank or chemical treatment system.
- Document all field observations and any deviations from standard sampling procedures.
- Obtain permission for access to and collection of samples and data from the well.

Table 4-10. Advantages and disadvantages of collecting water samples from supply wells with permanently installed pumps

Advantages
• Cost of well and pump installation is not a factor. • Samples from domestic and municipal wells (for studies of the quality of potable water supplies) are collected directly from the resource being studied. • Pumps are dedicated to the site; therefore, - cross-contamination of other wells from pumping equipment is not a problem, and - field time and effort otherwise expended in operating and cleaning portable pumps can be allocated to other tasks. • In-service supply wells generally require a minimal amount of purging at the time of sampling.
Disadvantages
• The well and the open or screened intervals might not isolate the aquifer zone where water-quality information is needed. • Materials of well and pump construction may affect concentrations of the analytes targeted for study. • Pumps with high capacities can alter the water chemistry of a sample if the pump is lubricated with oil. The water chemistry of a sample also can be altered by aeration and degassing caused by high-velocity pumping, suction lift, and cavitation. • Access for water-level measurements might be unavailable; or, access might be indirect (through an air line), thus yielding less accurate measurements.

Steps for sampling from water-supply wells



Ensure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies. Implement good field practices and *CH/DH* techniques, as applicable (duties typically performed by Clean Hands (*CH*) and Dirty Hands (*DH*) are indicated in the steps that follow). Check that you have the correct site and well folders, and a document (preferably signed) granting site access and well sampling and purging permission.

Step 1. Supply-well sampling: Safety and site preparations.

a. Upon arrival, set out safety equipment such as traffic cones and signs, as needed. Park vehicle in a position to prevent sample contamination from vehicle and traffic emissions and the prevailing wind.

   - Check the well identification number and compare it with the number in the well file and in field notes (section 4.2.1).
   - Assign *CH/DH* tasks.

b. Describe well and site conditions in field notes and on field forms, as appropriate (*DH*).

c. Check site for hazardous conditions (NFM 9) (*DH*).

   - Test for toxic fumes if the well is in an enclosed structure or if there is reason to suspect the presence of organic vapors.
   - Examine the area for evidence of animal infestation and other potential safety hazards.

d. Prepare an area to be used for field cleaning of equipment *(DH)*.

e. Set up equipment and instruments for field measurements and ground-water withdrawl *(DH)*.

- Calibrate field-measurement instruments (*DH*). Refer to NFM 6 for calibration information and instructions.
- Wearing disposable gloves, set up the sample-processing and sample-preservation chambers (usually in the water-quality field vehicle). *Change gloves*. Place the filter unit and other supplies that will be needed for the first sample into their respective chambers *(CH)*.

f. Spread clean plastic sheeting (polypropylene tarp, for example) on the ground around the well to keep sampling equipment, the well tape, and sample tubing off of the ground. Prepare area to be used for field cleaning of equipment (*DH*). Take care not to trample on the sheeting.

g. Determine the location and method of tubing hookup to the well. Connect sample tubing as close as possible to the wellhead *(DH)*.

i. There must be no water-storage tanks, holding or pressurization tanks, or chemical disinfection or water-softening systems connected in-line between the pump and tap/faucet to which sample tubing will be connected. Obtain written permission to install a tap if it is necessary for bypassing a holding tank or treatment system.

ii. Select a faucet without an aerator or obtain written permission to remove the aerator (replace it after sampling). Use connectors and sample tubing that will not contaminate the sample with respect to target analytes.

- Use only precleaned sample-contacting connectors and tubing.
- Check that you have the correct size and configuration of connector fittings, as compatibility varies amont types of plumbing.
- At highly contaminated sites, sample-contacting equipment either should be dedicated for that site or should be disposable.

iii. Connect a short length of sample tubing (2 to 3 feet) between the tap/faucet fitting and the antibacksiphon valve *(DH)*.

iv. Connect sample tubing from the antibacksiphon valve to the manifold; and from manifold to the flowthrough chamber, the sample-processing chamber, and the waste outlet.

- Select transparent, nonporous sample tubing and tubing to the flowthrough chamber for field measurements to be able to check for bubbles or sediment entrained in the sample flow. Sample tubing must be clean and of the appropriate material with respect to study objectives; flowthrough-chamber tubing can be of any material if used only in connection with field measurements. Keep the discharge end of the sample tubing sealed until use.
- Tubing used solely to discharge purge water to waste can be of any material (garden hose, for example), but must be long enough to transport wastewater away from the work area.

Step 2. Measure water level *(DH)*.

Procedures and equipment for water-level measurement depend on well type and construction and the presence of nonaqueous liquid phases. Important considerations and method limitations are described in Appendix A4-B.

a. Put on gloves if chalking a steel tape. Using a weighted steel or electric tape in a nonpumping well, measure water level to the nearest 0.01 ft (for wells <200 ft to water), starting at the permanent measuring (reference) point. Repeat the measurement until precision is within 0.02 ft (U.S. Geological Survey, 1980). At wells deeper than 200 ft, calculate the compensation factor to account for streching of the tape.

- Do not allow the well tape to contact the ground before inserting it into the well.
- Care must be taken not to entangle the well tape in the pump discharge pipe or intake.
- Do not use lead weights; use stainless steel or other noncontaminating material. An unweighted tape might be necessary if the weight cannot fit past the pump apparatus.
- At some supply wells, the water level only can be estimated using the less accurate air-line method. As a last resort if no water-level measurement can be made, use the measurement recorded on the driller's well log in order to calculate an estimated purge volume.

b. Water-level measurements must be recorded on field form(s) and in GWSI forms. On the field form, note any deviations from standard water-level measuring procedures. It is useful also to record water level in QWDATA (USGS Office of Water Quality Technical Memorandum 2006.01).

c. Clean the tape after each use to avoid cross-contamination of wells (see NFM 3.3.8).

Step 3. Purge the well and monitor field measurements *(DH).*

a. Calculate or estimate the well volume (the depth to the bottom of the well and the inside casing diameter must be known):

$$\mathbf{V = 0.0408 \times HD^2}$$

where,

V is volume, in gallons
H is height of water column
$\mathbf{D^2}$ is the inside well diameter squared, in inches.

b. Begin pumping to purge the well according to study objectives. Discharge the initial well water through the waste line until sediment is cleared from the flow.

- Supply-well pumps commonly are either on or off, with no variable-speed capability. To regulate the flow, use a maniforld with a needle valve, if possible.
- Open any additional valves or taps/faucets to ensure that the pump will operate continuously and reduce the possibility of backflow stored in ancillary plumbing lines; keep these open throughout purging and sample withdrawal.
- The pump should produce a smooth, solid stream of water with no air or gas bubbles and without pump cavitation during field measurements and sample withdrawal.
- **Do not halt or suddenly change the pumping or flow rate during the final phase of purging or while sampling.**
- Contain and dispose purge waters according to Federal, State, or local regulations. Do not discharge purge water from one well into another without proper authorization. Discharge purge water far enough away from the well or well cluster so as not to enter or affect water quality in the well, and to prevent muddy and slippery work conditions.

TECHNICAL NOTE: A supply well that is in regular service and that is pumping continuously or that has been operating long enough to have removed three casing volumes of water within several hours of sample collection does not require removal of three well volumes. Before withdrawing sample in this case, flush sample water through the tubing and monitor measurements.

- Field personnel could request a site operator or homeowner to start pumping the well before personnel arrive onsite.
- If the pump has been turned off but three well volumes were removed within 24 hours before sampling and samples only will be analyzed for nutrient or major-ion concentrations, additional purging is not necessary.
- Purging immediately before sampling is recommended if samples for trace elements and volatile organic compounds will be collected.

c. When the water runs clear, divert flow to the flowthrough chamber for field measurements (unless a downhole instrument is in use). Once the flow is constant (see instructions in step b), begin monitoring field measurements (refer to NFM 6 for detailed instructions); in addition, record the number of well volumes being discharged, the start and end times of purging, the pumping rate, water level, and location of the pump intake (fig. 4-12).

- To control the flow rate from the maniford, use a flow-regulating valve, such as a faucet or needle valve.
- Keep three-way valves either completely open or closed (partially open three-way valves can create a vacuum or air bubbles, and can draw in contaminating water). **Do not use a two- or three-way valve to regulate the flow.**
- **Recommended:** To ensure a representative sample, maintain the water level in the well above the screened or open interval.

d. As the final well volume (commonly the third well volume) is purged, calculate the final pumping rate and record on field forms at least five sets of field measurements determined at regularly spaced intervals while pumping at this rate. Referring to the instructions provided in NFM 6, check the field-measurement data against the measurement-stability criteria (fig. 4-12).

- To record the pumping rate of water flowing through more than one conduit, sum the rate of flow through each conduit.
- Routine field measurements for USGS studies include water temperature, conductivity, pH, dissolved oxygen, and turbidity.
- The final pumping rate, used during the final five sets of field measurements, also should be used during sample collection.

Step 4. Withdraw ground water (*CH*).

Maintain the same rate of pumping throughout sample withdrawal and collection as the rate used during withdrawal of the final purge volume.

a. Put on disposable gloves. Check that the sample tubing is properly secured within the sample-processing chamber.

b. Direct sample flow through the sample tubing to the processing chamber and channel two tubing volumes of the water to waste.

- **If samples will be collected for organic carbon analysis through equipment and tubing that previously was methanol-rinsed, flush at least five tubing volumes of sample water through the tubing (or collect the organic-carbon sample using a separate, non-methanol-rinsed sampler) before proceeding to Step 5.**
- Use the needle valve at the maniford to adjust sample flow as appropriate for the target analysis. Depending on the site-specific logistics, a second needle valve can be installed after the outlet end of the maniford and close to the sample-processing chamber. Avoid splashing or pooling water inside the chamber while processing sample and filling sample bottles.

Flow should be constant and uninterrupted while purging and sampling.

Step 5. Collect and process the sample → Refer to NFM 5, *Processing of Water Samples*, for instructions regarding the field rinse of sample bottles, sample filtration, and the collection and preservation of wholewater and filtered samples.

RULE OF THUMB: The rate of flow for filling sample bottles should not exceed

- 500 mL/min for bottles 250 mL or greater in volume,

or

- 150 mL/min for 40-mL VOC vials.

Step 6. Clean equipment → Refer to NFM 3, *Cleaning of Equipment for Water Sampling*. Sampling equipment must be cleaned as instructed in NFM 3 before leaving the field site.

At sites at which the level of contamination is suspected or known to exceed drinking-water standards or health advisories, use sample tubing that is disposable or dedicated to that site in order to minimize the risk of cross contamination between wells. Wear gloves while cleaning and handling sampling equipment.

- Rinse sampling equipment with deionized water before the equipment dries.
- Clean equipment to be used at another well during the same field trip after rinsing it and before moving to the next site.
- Collect field blanks to assess equipment-cleaning procedures directly after the sampling equipment has been cleaned in the field or after moving to the next site and before sampling, as dictated by the data-quality requirements of the study (section 4.3).

Monitor Wells 4.2.4.B

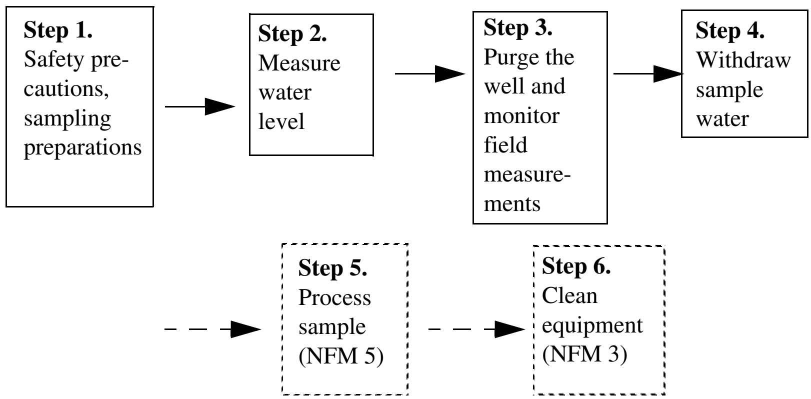
When selecting purging equipment for monitor wells, site conditions need to be considered. In general,a portable, submersible nonaerating pump that also will be used for sampling is recommended. The specific equipment and well-purging method selected, however, can depend on depth to water, length of the open interval, well construction, and site contamination. For example, to reduce the volume and time required for purging, especially in deep wells or in wells for which purge water is contaminated and must be contained, inflatable packers can be used to isolate the aquifer interval of interest.

In addition:

- ▶ When the water table is deeper than 250 ft and (or) a large volume of water must be purged, a dual-pump system can be used: position, in series, a submersible pump downhole and a centrifugal pump at the surface.
  - — Water discharging from the slow-pumping submersible pump is used for field measurements and sample collection, whereas the centrifugal pump removes the required volume of purge water at a faster rate. Changes in pumping rate might increase turbidity.
  - — Dissolved-oxygen concentration, Eh, or turbidity should not be measured while using a dual-pumping system. Record measurements while operating only the submersible pump.
- ▶ When the water table is less than 25 to 30 ft from land surface, a peristaltic pump can be used for small-diameter wells. A peristaltic pump or other comparable suction device can affect dissolved-oxygen concentrations and Eh measurements unless low gaseous-diffusion tubing such as Tygon® is used (NFM 2).
- ▶ An inflatable packer sometimes is set above and below the screened/open interval, with a pump intake located within the screened/open interval.
  - — Packers sometimes fail to form a complete seal between aquifer intervals, and should be used with pressure transducers located directly above and below the isolated interval to indicate whether water is leaking past the packers or short circuiting in the aquifer.
  - — The materials of which the packer is made also might affect sample chemistry by leaching or sorbing target analytes.

- ▶ A bailer is not recommended for purging. The plunging action of the bailer can release orstir up particulates that are not ambient in ground-water flow, resulting in biased measurements and analyses.

Steps for sampling at monitoring wells



Step 1. Monitor-well sampling: safety and site preparations.

a. Upon arrival, set out safety equipment such as traffic cones and signs, as needed. Park vehicle in a position to prevent sample contamination from vehicle and traffic emissions and prevailing wind.

- Check well-identification number (this should be indelibly marked on the well casing) and compare it with the well file and field notes (section 4.2.1).
- Assign *CH/DH* tasks.
- If a gasoline-powered generator is used, locate it downwind of sample collection or elsewhere to avoid sample contamination from fumes.
- Prepare an area to be used for field cleaning of equipment (*DH*)

b. Describe well and site conditions on field forms, as appropriate (*DH*).

c. Check site for hazardous conditions (NFM 9) (*DH*).

- Test for toxic fumes if the well is in an enclosed structure or if there is reason to suspect the presence of organic vapors.
- Examine the area for evidence of animal infestation and other potential safety hazards.

d. Spread a clean plastic sheeting (polypropylene tarp, for example) on the ground around the well to keep sampling equipment, the well tape, and sample tubing clean (*DH*). Take care not to trample on the sheeting.

e. Set up equipment and instruments for field measurements and ground-water withdrawal (*DH*). Locate a power supply source, if needed.

- Set up the pump and generator (if needed) in a location to avoid sample contamination from generator fumes.
- Calibrate field-measurement instruments (*DH*). (Refer to NFM 6 for calibration information and instructions.)
- Wearing disposable gloves, set up the sample-processing and -preservation chambers (usually in the water-quality field vehicle). Keep sample tubing as short as is practical and shaded from direct sunlight (to minimize changes in the temperature of the sample). *Change gloves.* Place the filter unit and other supplies that will be needed for the first sample into their respective chambers *(CH)*.

f. Remove the well cap. Verify clear access downhole by lowering a section of blank pipe through the depth interval to be sampled and raising it slowly. **Take care not to drop the pipe or otherwise stir up particulates in the process of lowering and raising the pipe** (*DH*)**.**

i. Connect the antibacksiphon valve in-line between pump and manifold (the antibacksiphon valve is a standard component of some submersible pumps).

ii. Use connectors and sample tubing that will not contaminate the sample with respect to target analytes.

- Use only precleaned sample-contacting connectors and tubing.
- At contaminated sites, sample-contacting equipment either should be dedicated for that site or should be disposable.

iii. From the manifold, connect the appropriate tubing to the flowthrough chamber, the sample-processing chamber, and the waste outlet.

- Select transparent, nonporous sample tubing and tubing to the flowthrough chamber for field measurements to be able to check for bubbles or sediment entrained in the sample flow.
- Tubing that transfers sample to the processing chamber must be clean and of noncontaminating material. Keep the discharge end of the sample tubing sealed until use.
- Flowthrough-chamber tubing can be of any material if used only in connection with field measurements.
- Tubing used solely to discharge purged water to waste can be of any material (garden hose, for example), but must be long enough to transport wastewater away from the work area.

Step 2. Measure water level (*DH*).

Procedures and equipment for water-level measurement depend on well type and construction and the presence of nonaqueous liquid phases. Important considerations and method limitations are described in Appendix A4-B-3, 4, and 5. Each well must have a designated measuring point that is indicated permanently on the well (Appendix A4-B-1).

a. Put on gloves before chalking a steel tape. Using a weighted steel or electric tape in a nonpumping well, record two or more consecutive water-level measurements to the nearest 0.01 ft (for wells of < 200 ft to water), starting at the permanent measuring (reference) point. Repeat the measurement until precision is within 0.02 ft (U.S. Geological Survey, 1980).

   - Do not allow the well tape to contact the ground before inserting it into the well. After measuring the water level, clean the tape (NFM 3.3.8) to avoid cross contaminating the next well.
   - Do not use lead weights, but weight the tape with stainless steel or another relatively noncontaminating material.
   - At wells deeper than 200 ft, calculate the compensation factor to account for stretching of the tape.

b. Record water-level measurement on field forms and in GWSI (USGS Office of Water Quality Technical Memorandum No. 2006.01). Note any deviations from standard water-level measuring procedures on field forms (fig. 4-12). It is useful also to record water-level data into QWDATA.

c. Set up a system to measure water levels throughout purging. Electrical tapes or submersible pressure transducers are recommended—repeated measurements with a steel tape can be cumbersome and can generate turbidity in the water column. If a packer system is used, installpressure transducers above and below the packer.

d. Clean the tape after each use to avoid cross contamination of wells (NFM 3.3.8).

RULE OF THUMB: The initial water-column height should be greater than 4 ft plus the length of the sampling device.

Step 3. Purge the well and monitor field measurements (*DH*)**.**

Purge monitor wells, preferably using a variable-speed pump (see the TECHNICAL NOTES listed at the end of step 6). Operate the pump in a manner that avoids or minimizes turbidity. **Do not use a bailer for purging** unless the well characteristics or other constraints exclude alternatives and the turbidity during and afterbailing is at the background level. **Recommendation:** Measure water levels throughout purging to document drawdown and the location of the water level with respect to the screened/open interval and the pump intake.

- ▶ Use the same pumping equipment for purging that will be used to collect samples, if possible.
- ▶ **Avoid refueling or changing equipment, and do not stop the pump during the final phase of purging and sample collection.** Be aware of study objectives and potential sources of contamination. For example, avoid fueling the generator on the same day that samples are collected for VOC analysis. Do not transport a generator or gas tanks in the water-quality field vehicle.
- ▶ Adjust the flow rate at the pump if using a variable-speed pump. If a constant-speed pump is used, adjust the flow rate using a needle valve.
  - — Pump at a rate that does not substantially lower the water level. Ideally, well yield should be sufficient so that the water level is maintained above the screened or open interval.
  - — Flow should not be halted or the flow rate changed suddenly during the final phases of purging and sampling.

a. Calculate the well volume. For a cased well, the depth to the bottom of the well and the inside casing diameter must be known:

V=0.0408 x HD2

where,
V is volume, in gallons
H is height of water column
$\mathbf{D}^2$ is the inside well diameter squared, in inches

Note that for a cased well, the volume of water stored within the annular space between the well screen and borehole well also should be evacuated at least once.

b. Lower a submersible pump, followed by a water-level sensor, to the desired location of the pump intake. (The pump position is fixed if the monitoring well has a permanently installed sampling system.) Move the equipment slowly and smoothly through the water column to avoid stirring up particulates. The intake can be either lowered continually while purging to the final depth desired or placed immediately at its final position. **Note that the final pump intake position always is at the point of sample collection.**

- Position the pump intake about 3 ft (about 0.9 m) below static water surface and a minimum distance above the top of the screened/open interval of 7 to 10 times the well diameter (for example, 14 to 20 in. for a 2-in. well diameter), if the sample is to represent the entire screened or open interval of aquifer. The location of the intake might be different if the study objective requires collecting the sample from a point within the screened/open interval or from wells in which packers are installed.
- Place water-level sensor (electric tapes) a maximum of 1 ft (about 0.3 m) below the water surface.

c. Position the pump intake.

- **If final intake position is above the screened or open interval, do not exceed 1 ft (about 0.3 m) of drawdown.**
- **If final intake position is within the screened or open interval, do not exceed 0.5 ft (about 0.15 m) of drawdown.** The final pumping rate should be as slow as necessary to avoid causing turbidity.

d. Start the pump, channeling initial discharge to waste. Discharge the initial well water through the waste line until sediment is cleared from the flow.

- Gradually increase and (or) adjust the pumping rate to limit drawdown to between 0.5 and 1 ft (about 0.15 to 0.3 m), if possible.
- **If using a variable-speed pump, adjust the rate of flow at the pump.** If using a constant-speed pump, control the flow rate using a needle valve (fig. 4-10).

- **Do not use a three-way valve or flow-splitting valve to adjust flow rate.** It is necessary to keep the two- or three-way valves either completely open or completely closed (partially open three-way valves can create a vacuum or air bubbles, and can draw in contaminating water).
- **Contain and dispose of purge waters according to Federal, State, or local regulations.** Do not discharge purge water from one well into another without proper authorization. Discharge purge water far enough away from the well or well cluster so as not to enter or affect water quality in the well, and to prevent muddy and slippery work conditions.

e. When the water runs clear, divert flow through the manifold to the flowthrough chamber (unless a downhole instrument is being used for field measurements.

- **The flow should be a smooth, solid stream of water with no air or gas bubbles and without pump cavitation** during field measurements and sample withdrawal. Adjust the pumping rate to eliminate air or gas bubbles or cavitation, but do not halt or suddenly change the flow rate.
- **Record the start time of purging, the pumping rate(s), water level(s), and final location of the pump intake** (fig. 4-12). If water is flowing through more than one conduit (such as valve and manifold lines), calculate the flow rate by summing the flow rate through each conduit.
- **Begin monitoring field measurements** (refer to NFM 6 for instructions) once flow to field-measurement instruments is constant (see instructions above).
- **Do not move the pump or change the rate of pumping during field measurements or sample collection after setting the intake at its final depth location.**

f. **Purge a minimum of three well volumes or the purge volume dictated by study objectives.** (Check exceptions to the three-well-volume procedure described in section 4.2.3.B).

- Record water levels and field measurements at regular time intervals (fig. 4-12; NFM 6). Routine field measurements for USGS studies include water temperature, conductivity, pH, dissolved-oxygen concentration, and turbidity. Check for special instructions regarding field-measurement or field-analysis requirements based on study objectives.
- As the final well volume (commonly the third well volume) is purged, check the field-measurement data against the measurement-stability criteria (fig. 4-12). Record at least five sets of field measurements determined at regularly spaced intervals, which indicate that measurement values are relatively constant (have "stabilized") or that stabilization cannot be achieved in the given time interval (NFM 6).

Step 4. Withdraw the sample (*CH*).

Pumped samples—

Maintain the same rate of pumping throughout sample collection as the rate used during withdrawal of the final purge volume.

a. Put on disposable gloves. Check that the sample tubing is properly secured within the sample-processing chamber.

b. Direct sample flow through the sample tubing to the processing chamber and channel two tubing volumes of the water to waste. Use the needle valve at the maniford (fig. 4-10) to adjust sample flow as appropriate for the target analysis.

- Depending on the site-specific logistics, a second needle valve can be installed after the outlet end of the maniford and close to the sample-processing chamber.
- The flow should be smooth and non-turbulent. Avoid splashing or pooling water inside the chamber while processing sample and filling sample bottles.
- **If samples will be collected for organic carbon analysis through equipment and tubing that previously was methanol-rinsed, flush at least five tubing volumes of sample water through the tubing (or collect the organic-carbon sample using a separate, non-methanol-rinsed sampler) before proceeding to step 5.**

Remember, flow should be constant and uninterrupted while purging and sampling.

RULE OF THUMB: When using a pump, the rate of flow for filling sample bottles should not exceed

- 500 mL/min for bottles 250 mL or greater in volume,

or

- 150 mL/min for 40-mL VOC vials.

Nonpumped samples—

a. Field rinse the sampler (typically, a bailer) and sampler emptying device (and compositing device, if used) three times before collecting the sample. Deploy the sampler so as to minimize disturbance to the water column and aquifer materials.

   i. Use a reel to keep sampler line clean and untangled.

   ii. Lower sampler smoothly, entering water with as little disturbance as possible.

   iii. Allow sampler to fill, then withdraw sampler smoothly.

   iv. Shake water in sampler vigorously to rinse all interior surfaces.

   v. Attach sample-delivery tube or bottom-emptying device to sampler and drain the rinse water through the sampler.

   vi. Repeat rinse procedure at least twice.

b. Repeat steps (a) i-iii to withdraw ground water for the sample.

   TECHNICAL NOTE: When a device is lowered and raised through the water column, the disturbance to the water column can result in outgassing or degassing of ambient dissolved gases and an increase in concentrations of suspended particulates. Repeated movement of the device through the water column exacerbates these effects and can result in substantial modification of the ambient water composition and chemistry.

c. Set up the bailer in an enclosed or protected space.

Step 5. Process/collect the sample →Refer to NFM 5, *Processing of Water Samples*, for instructions regarding the field rinse of sample bottles, sample filtration, and the collection and preservation of whole-water and filtered samples.

Step 6. Clean equipment →Refer to NFM 3, *Cleaning of Equipment for Water Sampling*. Sampling equipment must be cleaned as instructed in NFM 3 before leaving the field site.

At contaminated sites, use sample tubing that is disposable or dedicated to that site in order to minimize the risk of cross contamination between wells. Wear gloves while cleaning and handling sampling equipment.

- Rinse sampling equipment with deionized water before the equipment dries.
- Clean equipment to be used at another well during the same field trip after rinsing it and before moving to the next site.
- Collect field blanks to assess equipment-cleaning procedures directly after the sampling equipment has been cleaned in the field or after moving to the next site and before sampling, as dictated by the data-quality requirements of the study (section 4.3).