WELL INSTALLATION AND DOCUMENTATION, AND GROUND-WATER SAMPLING PROTOCOLS FOR THE PILOT NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

By Mark A. Hardy, P. Patrick Leahy, and William M. Alley

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CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSION TABLE

For the use of readers who prefer to use metric units (International System), conversion factors for inch-pound units used in this report are listed below.

Multiply inch-pound unit	*By*	*To obtain metric unit*
foot (ft)	0.3048	meter
foot per second (ft/sec)	0.3048	meter per second
gallon (gal)	0.003785	cubic meter
gallon per minute (gal/min)	0.003785	cubic meter per minute
inch	25.4	millimeter
square mile	2.590	square kilometer

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}F = 1.8\ (^{\circ}C) + 32$$

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ABSTRACT

The U.S. Geological Survey is currently (1989) undertaking a pilot National Water-Quality Assessment Program. The purpose of the pilot program is to test and refine concepts for a possible full-scale National Water-Quality Assessment Program that would provide a consistent description of the current status and trends in water quality across the Nation and insight into the major human and natural factors that control water quality in different regions. Seven pilot project areas are included in the pilot program; four focus on surface water and three focus on ground water.

This report presents criteria that are generally applicable for the conduct of ground-water field activities in the pilot project areas. Consistent criteria are described for selecting and documenting wells, installing new wells, and sampling from wells for selected water-quality constituents.

INTRODUCTION

Background

Beginning in 1986, the Congress annually has appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The long-term goals of the program are to describe the status and trends in the quality of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources.

The NAWQA Program is organized into study units on the basis of known hydrologic systems (major river basins and large parts of aquifers or aquifer systems). The study units are large, involving areas of a few thousand to several tens of thousands of square miles.

At present (1989), the assessment program is in a pilot phase. Seven project areas, representing a diversity of hydrologic environments and water-quality conditions, were selected for the pilot program. The seven pilot project areas include four that focus primarily on surface water and three that focus primarily on ground water. The surface-water pilot project areas are the lower Kansas River basin in Kansas and Nebraska; the Kentucky River basin in Kentucky; the Upper Illinois River basin in Illinois, Indiana, and Wisconsin; and the Yakima River basin in Washington. The ground-water pilot project areas are the Carson River basin in Nevada and California; the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.

Purpose and Scope

The purpose of this report is to describe criteria that will be used in the pilot NAWQA Program for selecting and documenting characteristics of wells, installing new wells, and sampling from wells for selected water-quality constituents. The scope of this report includes only those guidelines that are generally applicable to all three ground-water pilot projects. Special field procedures required for the unique hydrogeologic settings and water-quality issues of particular projects are documented separately in reports that result from those projects. For example, sampling procedures described in this report apply only to those water-quality constituents analyzed in samples from all three projects. Alternative sampling procedures may be required for constituents unique to each project.

This document has a specific purpose and scope related to the pilot NAWQA Program and is not a general purpose field manual. The report provides criteria that will ensure that comparable data are collected in the pilot program. Ultimately, these data will be used for accomplishing the long-term goals of the proposed full-scale NAWQA Program. The report supplements (1) a report that describes the concepts for a NAWQA Program (Hirsch and others, 1988), (2) a quality-assurance plan for the pilot NAWQA Program (Mattraw and others, 1989), and (3) both published technical documents (for example, Wood, 1976; Claassen, 1982; Shuter and Teasdale, 1989) of the Geological Survey and internal technical memorandums relating to field techniques.

Acknowledgments

Members of the three ground-water pilot projects contributed greatly to the development of this report. In particular, L. Joseph Bachman, David L. Parkhurst, and Alan H. Welch provided initial written comments on proposed field procedures for the projects and provided many insightful comments during the development of this report. Michael T. Koterba and Mark W. Sandstrom provided valuable comments on sampling and quality assurance. Elizabeth A. Frick helped to design the land-use and land-cover field sheet.

WELL DOCUMENTATION AND SELECTION

Both existing wells and newly constructed wells will be sampled as part of the NAWQA pilot projects. A general policy of the pilot NAWQA Program is to sample only from those existing wells for which information on well construction and the local hydrogeology is sufficient to (1) determine the hydrogeologic unit from which the well is producing, and (2) assure that the well is suitable for sampling the constituents of concern. In particular, this includes information on the depth of the well, depth to the top and bottom of each open interval, the hydrogeologic unit(s) to which the well is open, the casing type, and the pump type. In some instances, these characteristics will not be known completely for all wells that are candidates for sampling. Dependent on the situation, the most suitable of the candidate wells will be selected for sampling, or a new well will be constructed.

In general, wells selected as potential sampling sites will be visited prior to sampling, and the existing data for these wells will be field checked and verified to the extent possible. A sampling network that meets the program objectives will be selected from this group of wells.

Wells that are sampled need to be located accurately. Determining the location of wells will be accomplished primarily by computing latitude and longitude from Geological Survey 7 1/2-minute quadrangle maps. This procedure generally is considered to be accurate to the nearest 5 seconds. Public land system (PLS) coordinates will be used, where available, in addition to latitude and longitude. In instances when greater accuracy in location is needed, horizontal and vertical control will be determined by standard second-order surveying techniques (Davis and others, 1966, p. 887).

Two forms will be used to record information on wells. Site schedules in common use by individual Geological Survey offices will be used to collect data that will be stored in the Geological Survey Ground-Water Site-Inventory (GWSI) File. In addition, a land-use and land-cover field sheet developed specifically for the pilot NAWQA Program will be used.

In general, as much well construction information as possible will be obtained and recorded on the appropriate site schedule form. Table 1 lists site characteristics that will be emphasized on the site schedule form. This information may help resolve questions concerning sampling results and their interpretation. It is important to have accurate data on the well's construction, because the construction affects the hydrogeologic units from which the well is producing and may influence the composition of water withdrawn from the well. The well construction also determines the type of equipment needed to sample the well.

Well information can be derived from a number of sources including data files maintained by the U.S. Geological Survey, State, and local agencies; the well driller; and possibly the well owner. Data on well construction often will come from available records. However, during the preliminary site visit, additional data on well construction frequently will be collected and available data verified to the extent possible.

In addition to the data stored in GWSI, table 2 lists four characteristics that will be recorded in the U.S. Geological Survey Water-Quality File each time a well is sampled. This information includes the purpose for sampling the well and the sampling method.

The land-use and land-cover field sheet is shown in figure 1. The purpose of the field sheet is to document land use and land cover in the vicinity of each well. This information will be used to help explain water-quality sampling results.

The field sheet is to be completed in its entirety the first time a well is sampled. The field sheet for a well then will be checked each subsequent time a well is sampled and any changes noted on a new sheet. A special computer file has been developed for the pilot NAWQA Program to store information from the land-use and land-cover field sheets (Jonathan C. Scott, U.S. Geological Survey, written commun., 1989).

In addition to completing the land-use and land-cover field sheet, the following photographs generally will be taken at each well: (1) One photograph of the well and surrounding area as seen when approaching the well; (2) one closeup photograph of the well and water-level measuring point; (3) four photographs that show the area near the well (These photographs will be taken to the north, east, south, and west. After the film has been developed, the direction of the photographs from the well will be clearly labeled); and (4) any number of additional photographs to document features that could influence the quality of water at the well.

Special care will be taken to identify on the photograph the measuring point used for water-level measurements and the sampling point used for

Table 1.--*Site characteristics recorded in the Ground-Water Site-Inventory File to extent possible at all sampled wells*

Code	Site characteristic
C1	Site ID (station number)
C2	Type of site
C3	Data reliability
C4	Agency code
C5	Project number
C6	District code
C7	State code
C8	County code
C9	Latitude
C10	Longitude
C11	Latitude-longitude accuracy code
C12	Local well number
C16	Altitude of land surface, in feet
C17	Method used to determine altitude
C18	Accuracy of altitude
C19	Topographic setting
C23	Primary use of site
C24	Primary use of water
C28	Depth of well, in feet
C29	Source of depth data
C43	Type of lift
C60	Date of well construction
C65	Method of construction
C66	Type of finish
C67	Type of surface seal
C80	Casing material
C83	Depth to top of open interval, in feet (for each open interval)
C84	Depth to bottom of open interval, in feet (for each open interval)
C91	Depth to top of geohydrologic unit, in feet (for each unit)
C92	Depth to bottom of geohydrologic unit, in feet (for each unit)
C93	Lithologic unit identifier (for each unit)
C161	Well owner
C235	Date water level measured
C237	Water level, in feet below land surface
C238	Status of well at time of water-level measurement
C239	Method used to measure water level
C268	Rated capacity of pump, in gal/min
C276	Accuracy of water-level measurement
C321	Begin data for use of water-level measuring point
C322	End data for use of water-level measuring point
C323	Height of water-level measuring point
C324	Description of water-level measuring point
C713	Aquifer-type code
C714	Primary aquifer

Table 2.--*Site characteristics that will be recorded in the Geological Survey Water-Quality File each time a well is sampled*

Code	Site characteristic
71999	Sample purpose code (Record a value of 15 to indicate that this sample was collected as part of the National Water-Quality Assessment Program)
84144	Well-selection criteria 100 - Well selected for sampling because site is near or within a known or suspected local problem area. 200 - Well selected for sampling primarily without regard to any known or suspected local problem areas.
84145	Project component 100 - Regional or survey sampling 200 - Targeted sampling (Agricultural area) 300 - Targeted sampling (Urban or suburban area) 400 - Targeted sampling (Naturally occurring substances) 500 - Targeted sampling (Local-scale network) 600 - Targeted sampling (Other) 700 - Geochemical investigation
84164	Sampler type 4010 - Thief sampler 4020 - Bailer (open top) 4025 - Bailer (double valve) 4030 - Suction pump 4040 - Submersible pump 4050 - Squeeze pump 4060 - Gas reciprocating pump 4070 - Gas lift 4080 - Peristaltic pump 4090 - Jet pump 4100 - Flowing well 4110 - Resin trap collection 8010 - Other

LAND USE AND LAND COVER FIELD SHEET - GROUND-WATER NAWQA PILOT STUDIES page 1 (07/88)

DATE FIELD CHECK ___/ ___/ ___ PERSON CONDUCTING FIELD INSPECTION ____________
WELL STATION ID ____________ LATITUDE ________ LONGITUDE ________
LOCAL NUMBER _____ T ___ N/S R ___ E/W ___ ______ PROJECT ID ____________

1. TOPOGRAPHIC SETTING OF WELL ____________ (alluvial fan; playa; stream channel; local depression; dunes; flat surface; flood plain; hilltop; sinkhole; lake, swamp, or marsh; mangrove swamp; offshore (estuary)); pediment; hillside (slope); alluvial or marine terrace; undulating; valley flat; upland draw - descriptions in Watstore Manual v. 2, chap. II, p. B-19)

2. LAND USE AND LAND COVER CLASSIFICATION - (modified from Anderson and others, 1976, p. 8) Check all land uses that occur within each approximate distance range from the sampled well. Identify the predominant land use within each distance range and estimate its percent of the total area (0-25, 26-50, 51-75, or 76-100%) within a 1/4 mile radius of the well.

Land use and land cover	<100 ft	100 ft to 1/4 mile	Comments
I. URBAN OR BUILT-UP LAND			
--Residential			
--Commercial			
--Industrial			
--Other urban land (specify)			
II. AGRICULTURAL LAND			
--Cropland			
-nonirrigated			
-irrigated			
--Pasture			
--Orchard, grove, vineyard, or nursery			
--Confined feeding operation			
--Other agricultural land (specify)			
III. RANGELAND			
IV. FOREST LAND			
V. WATER			
VI. WETLAND			
VII. BARREN LAND			

3. AGRICULTURAL PRACTICES - Describe agricultural practices within 1/4 mile of the sampled well.

a. EXTENT OF IRRIGATION - Circle applicable statement.

nonirrigated, supplemental irrigation in dry years only, irrigated

b. METHOD OF IRRIGATION - Circle those that apply.

spray, flood, furrow, drip, chemigation, other (specify) ____________

c. SOURCE OF IRRIGATION WATER - Circle those that apply.

Ground water, surface water, spring, sewage effluent (primary, secondary, or tertiary treatment)

d. PESTICIDE AND FERTILIZER APPLICATION - Provide information about present and past pesticides and fertilizers used, application rates, and application methods.

e. CROP AND ANIMAL TYPES - Provide information about present and past crop and animal types, and crop rotation practices.

Figure 1.--Land-use and land-cover field sheet, pilot National Water-Quality Assessment Program

LAND USE AND LAND COVER FIELD SHEET - GROUND-WATER NAWQA PILOT STUDIES page 2 (07/88)

4. LOCAL FEATURES - Check all local features that may affect ground-water quality which occur within each approximate distance range from the sampled well.

Feature	<100 ft	100 ft to 1/4 mile	Comments
Gas station			
Dry cleaner			
Chemical plant or storage facility			
Airport			
Military base			
Road			
Pipeline or fuel storage facility			
Septic field			
Waste disposal pond			
Landfill			
Golf course			
Stream, river, or creek (perennial/ephemeral)			
Irrigation canal (lined/unlined)			
Drainage ditch (lined/unlined)			
Lake (natural/man-made)			
Reservoir (lined/unlined)			
Bay or estuary			
Spring (geothermal (>25°C)/ nongeothermal)			
Salt flat or playa (dry/wet)			
Mine, quarry, or gravel pit (commodity mined, active/abandoned)			
Oil well			
Major withdrawal well			
Waste injection well			
Recharge injection well			
Other			

5. LAND-USE CHANGES - Have there been major changes in the last 10 years in land use within 1/4 mile of the sampled well? Yes__ Probably__ Probably not__ No__ If yes, describe major changes.

6. ADDITIONAL COMMENTS - Emphasize factors that might influence local ground-water quality.

Figure 1.--Land-use and land-cover field sheet, pilot National Water-Quality Assessment Program--Continued

production wells. In some cases, these photographs may help in locating the site at a later date. The date the photograph was taken will be marked on the back of each photograph. The photographs, which will be a record of current land use near the well, may be useful in defining changes in land use that have occurred between sampling periods. These photographs and the land-use and land-cover field sheet for each sampling site will be stored in the local Geological Survey office site schedule file.

Information pertaining to the accessibility of the site also will be documented in the site schedule file. Examples of pertinent information include the site owner, contacts necessary for permission to sample, special constraints that may affect when the well can be sampled, and procedures needed to gain access to the well. Whenever possible, wells that have the potential for long-term access will be selected as sampling wells.

Observation and production wells will be included in the sampling network. In contrast to observation wells, production wells have the advantage of yielding large volumes of water and having pumping equipment in place. However, there are distinct disadvantages to production wells. For example, (1) the existing pumping equipment may affect water quality, (2) certain well construction features may not be desirable, and (3) access for sampling and water-level measurement may be difficult. The impact of each of these three factors is discussed below.

The type of pumping equipment may affect the suitability of water samples for some chemical analyses. For example, oil-lubricated pumps may contaminate samples that are collected for analysis of some organic constituents. For this reason, older turbine pumps, which commonly are oil-lubricated, will be avoided when sampling for organic compounds. In addition, wells that cavitate during pumping may affect the chemistry of the water withdrawn and will be avoided.

Well construction features of production wells also may affect the water quality. For example, if threaded steel casing and couplings were used, it is probable that the threads were coated with grease prior to installation. This grease is a potential contaminant to samples collected for some organic analyses. Also, the location of the pump intake is important in terms of purging the well prior to sampling.

Wells that are screened or open to more than one interval will be avoided, to the extent possible, because of uncertainties concerning the source of the sampled water. However, if a multi-screened well is the only available well within an area of interest, it may be necessary to include it in the sampling network to insure adequate spatial coverage. If the screened or open intervals are within the same aquifer, this problem is less of a concern than if the screened or open intervals are in multiple aquifers.

It is also important to consider the borehole hydraulics of a well prior to purging and sampling. Reilly and others (1989) have shown that observation wells with long screens in some hydrogeologic settings may have substantial well-bore flow. Sites where this natural flow within the borehole may be substantial should be avoided; instead, wells with a short screen or open interval should be selected for sampling.

In addition to the screened or open interval of a well, the location of the gravel pack may have a major influence on the hydrogeologic units from which the well is producing. Many wells have short screens or open intervals but are gravel packed from the bottom of the well to the base of the seal, several feet below the land surface. Other factors constant, wells with short gravel-packed intervals generally are preferred.

The accessibility of a sampling point is an important consideration in selecting a production well for sampling. Most wells will have an access point that can be identified during a field check prior to sampling. This access point should be located as near as possible to the wellhead, before on-site treatment, a pressure tank, or a holding tank.

Finally, certain criteria for well selection will arise from the specific objectives for a given well network. For example, potential sites that have a complex mix of land uses should be avoided for special studies of the effects of land use on ground-water quality because interpretation of the data would be difficult.

INSTALLATION OF NEW WELLS

Some wells will be installed by the pilot project teams to sample shallow ground water (generally to depths less than 50 feet). The installation of these wells will involve the selection of techniques for drilling, coring and sampling, and related items. The selection of the best suited techniques is important for the NAWQA pilot studies to ensure the collection of representative water-quality data. Shuter and Teasdale (1989) discuss in detail a number of techniques for drilling, coring and sampling, and well development for test holes and wells.

Depending on the drilling capabilities available to each pilot project, drilling services may be contracted for the installation of these wells. The type of well installation provided by contractors will depend on local industry standards in each pilot project area. The pilot project staffs will evaluate the types of well construction available and select the best techniques. Contracts will be prepared that will specify drilling or augering techniques that minimize the introduction of drilling fluids into the ground-water system. The following are general guidelines for well installation.

Preparation for Drilling

When sites are selected for potential well installation:

(1) Make site visit to assess conditions;

(2) Acquire necessary well drilling permits and approvals from the site owner and Federal, State, and local regulatory authorities;

(3) Establish utility clearances. A commercial line-locating service may be used for this purpose. However, this service usually covers only transcontinental gas pipelines, phone utility lines, and electric utility lines. Local sewer lines, water lines, and in some cases, site specific electrical service must be located in coordination with local authorities or property owners; and

(4) At a minimum, meet all local, State, and Federal regulations governing well drilling activities.

Drilling Techniques

Numerous techniques can be used to install shallow wells. Those techniques that will be used by the NAWQA pilot projects are (1) hollow-stem continuous flight augering, (2) solid-stem continuous-flight augering, (3) rotary drilling, and (4) for very shallow depths, use of a soil auger to drill a pilot hole followed by installation of casing driven by hand.

All drilling methods have disadvantages for ground-water monitoring. For example, some of the advantages and disadvantages of hollow-stem augering are enumerated in table 3. Hollow-stem augering has several advantages, including coring capabilities. One problem with the use of augers is that cross contamination can occur as cuttings are rotated upwards on the auger flights. Keely and Boateng (1987a, 1987b) present a method to decrease the effects of this problem. Their approach involves driving a temporary casing to shield one stratum from another.

Solid-stem augering has the potential for caving problems during coring and casing. If solid-stem augering is used and caving is a problem, one solution may be to auger to the top of the saturated zone and then drive casing several feet (ideally at least 5 feet) into the saturated zone.

Rotary drilling generally will be avoided for wells sampled for trace organic compounds. When rotary drilling is used, the casing of the completed well should be at least 4 inches in diameter to allow for proper development of fines in the aquifer material surrounding the screen. The drilling mud, if used, should be specified as sodium bentonite, free of added organic materials. Concerns about using drilling mud include the potential for cross-contamination of strata exposed to circulating mud in the borehole and the potential introduction of oils and other contaminants by the mud pump. Compressed air (air-rotary drilling) may be used rather than mud to cool the drill bit and to remove cuttings from the borehole. However, unless the air is filtered, oils and other contaminants may be introduced into the borehole from the air compressor (Keely and Boateng, 1987a). In addition, the introduction of air may result in chemical changes in the aquifer water and require extensive well development prior to sampling. Additives sometimes used in air rotary drilling will be avoided when drilling wells.

Flights, drill rods, bits, and core barrels will be washed with clean water before beginning augering or drilling; they will be steam cleaned if obvious contaminants were encountered or suspected in the soil or aquifer materials at the previous site. The augering and drilling equipment will be visually inspected for hydraulic fluid leaks, as these are potential sources of contamination. Also, Teflon[1] tape will be used as needed on couplings for drill rods, bits, and core barrels. Nonpetroleum based lubricants and pure petroleum jelly can be used for this purpose but are less desirable.

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[1]The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 3.--*Advantages and disadvantages of hollow-stem augering*

[Modified from Gillham and others, 1983]

Advantages	Disadvantages
• Can avoid the use of foreign fluids.	• Can cause vertical mixing of formation water and geologic materials.
• Can avoid the use of lubricants.	• Possible contamination from metal components.
• Suitable for collecting geologic samples.	• Limited to unconsolidated geologic materials without large rocks.
• Water samples can be collected. during drilling.	• Limited to depths of about 30-50 meters (100-165 feet).
• Sand packs and seals can be positioned accurately.	• Unconsolidated materials may surge into the hollow stem preventing desired placement of screens.
• Relatively inexpensive.	
• Auger rigs are mobile and are readily available.	

Aquifer-Material Sampling

Core samples often will be collected for analysis of the aquifer material. In general, this involves driving a sampling tube in advance of the drill bit. Commonly used coring devices are the split-spoon sampler and the Shelby tube. These samplers can be used with both hollow-stem and solid-stem augers. In general, the split-spoon sampler is used in unconsolidated material where large-size fragments of rock are not present. One advantage of the Shelby tube is that the resulting core can be used for the extraction of pore water and for other hydraulic analyses. Cores of near-surface materials (0-20 ft) may also be taken using a vibra-corer (Finkelstein and Prins, 1981). The vibracorer produces a continuous core with minimal disturbance of layered and bedded structures.

Well Construction

Well construction includes selecting casing materials and using appropriate techniques for sealing the annular space surrounding the casing. National Sanitary Foundation (NSF) approved PVC casing will be used, particularly schedule 40 flush-threaded casing. In certain situations, the stronger schedule 80 casing will be used. Advantages and disadvantages of different types of casing couplings are presented in table 4. If shallow wells need to be driven by hand, stainless steel casing is appropriate. Either 2-inch- or 4-inch-diameter casing will be used. The 4-inch casing is recommended, because it easily accommodates pumps and water-level recorders. Well screens will be made of PVC or stainless steel and typically will be 3 to 5 feet in length. In consolidated aquifer material, a 10-foot slotted pipe or open hole may be used instead of a well screen. The slot size will be selected based on the grain size of the aquifer material (Driscoll, 1986, p. 435-438). Where this approach is impractical, the slot size will be determined by a review of well construction records for nearby wells or by general knowledge of the area.

In general, the top of the well screen will be placed at least 5 feet below the average water-table altitude to reduce the probability that the well will be dry during parts of the year. However, for some special investigations, the well screens may be finished closer to the water table. Seasonal fluctuations at nearby observation wells will be examined, as needed, to determine the placement of well screens.

Prior to the installation of casing and screen, the materials should be in a contamination-free condition. A detergent wash is generally required. Steam cleaning or a high-pressure water spraying technique with low sudsing soap or detergent is preferable (Richter and Collentine, 1983). Table 5 lists some decontamination solutions. As an alternative to washing, casing can be purchased that is precleaned and wrapped in plastic. This approach eliminates the need for cleaning, but the casing is more costly.

The wells will be completed by grouting and sealing. A comparison of grouting materials is presented in table 6. Guidelines for completing wells are as follows. Backfill with a well sorted, washed sand opposite the screen. This sand pack shall consist mainly of quartz, contain no limestone or other calcareous material, such as shell fragments, and contain no organic material such as wood fragments or lignite. The particle size of the pack shall be consistent with the prevailing grain size of the aquifer material. A 1-foot plug of fine-grained quartz sand should be placed above the sand pack. This plug will prevent the seal material from infiltrating the pack. If installation of this plug is impractical, the

Table 4.--*Fitting types for well casing*

[Modified form Driscoll, 1986]

Type	Advantages	Disadvantages
Plain square ends (no fittings to weld)	• Readily available in pipe and screen. • No need to purchase threads and couplings.	• Special equipment and skills needed to field-weld metals. • Plastics are welded using solvent cement which causes the following problems: --Cementing procedures are very temperature and moisture sensitive. --Cements must be cured after application. --Cements may interfere with ground-water-quality analysis. Time spent welding may cause this type of fitting to actually cost more than threads.
Threads and couplings, riveted joints	• No solvents needed. • Lengths of pipe and screen joined relatively quickly. • Readily available. • Reasonably priced.	• May be difficult to get filter pack and/or grout past the lip of couplings. • May need to wrap threads with Teflon tape to make connections watertight.
Flush threads	• No solvents needed. • No couplings needed; filter packing and grouting simplified. • Lengths of pipe and screen joined quickly. • Readily available. • Reasonably priced.	• May need to wrap threads with Teflon tape to make connections watertight • Threads generally not compatible from manufacturer to manufacturer.

Table 5.--*Decontamination solutions*

[Modified from Richter and Collentine, 1983]

Name of solution	Remarks
Sodium bicarbonate	Effective for acids and bases, amphoteric, 5-15 percent aqueous solution.
Sodium carbonate	Effective for inorganic acids, good water softener, 10-20 percent aqueous solution.
Trisodium phosphate	Good rinsing solution or detergent, 10 percent aqueous solution.
Calcium hypochlorite	Excellent disinfectant, bleaching and oxidizing agent, 10 percent aqueous solution.

Table 6.--*Grouting materials for monitoring wells*

[Modified from Driscoll, 1986]

Type	Advantages	Disadvantages
Bentonite	• Readily available. • Inexpensive. • Pellets and granules are easy to use. • Remains plastic and will not crack.	• May produce chemical interference with water-quality analysis. • May not provide a complete seal because: --There is a limit (14 percent) to the amount of solids that can be pumped in a slurry. Thus, there are few solids in the seal; should wait for liquid to bleed off so solids will settle. --During installation, bentonite pellets may hydrate before reaching proper depth, thereby sticking to formation or casing and causing bridging. Use of a Tremie pipe will help alleviate this problem. --Cannot determine how effectively material has been placed. --Cannot assure complete bond to casing.
Cement	• Readily available. • Inexpensive. • Can use sand and/or gravel filter. • Possible to determine how well the cement has been placed by temperature logs or acoustic bond logs.	• May cause chemical interferences with water-quality analysis. • Requires mixer, pump, and tremie pipe: generally more cleanup than with bentonite. Contamination may be introduced by pump. • Shrinks when it sets; complete bond to formation and casing not assured. However, expanding cement is available to alleviate this disadvantage. Expanding cement contains bentonite and may cause chemical interferences.

sand pack should extend 5 to 10 feet above the top of the screen. However, the sand pack should not cross any confining units, thereby allowing flow from multiple aquifers to the well. The remainder of the annular space should be filled with bentonite or native sediment. Bentonite generally is preferred over native sediment to minimize contamination due to flow in the well's annular space. Cement may be used instead of bentonite in areas where high sulfate or saline waters are present. If native sediment is used to fill the annular space, a plug of at least 5 to 10 feet of bentonite should be placed on the sand pack or plug of fine-grained sediment. Bentonite is available in powder, granular, and pellet form. Granules generally will be used for the relatively shallow wells installed by the projects. The seal shall begin at the top of the 1-foot plug or sand pack and progress upward to within the depth affected by frost or within 3 feet of the land surface, so as to insure a continuous, effective seal. The uppermost part of the annular space will be filled with expanding cement within the depth affected by frost or as acceptable to local regulatory agencies.

As needed, a surface casing of steel will be installed at a height of about 4 feet to protect the well and to provide a base for possible water-level recorders. At some sites, it may be necessary to finish the well at or below the land surface. These wells will be designed, as needed, with watertight plugs or caps to prevent the entry of surface runoff to the well. At these sites, temporary shelters will be designed for any water-level recorders in use.

Well Development

During well development, the mud cake produced by the drilling process is cleaned off, and the small-sized particles are removed from the well. The procedure permits ground water to flow more easily into the well and helps to provide water free of suspended solids for sampling. The following techniques can be used for well development:

Surge block - A surge block slightly smaller in diameter than the well casing can be hand operated to depths of 40 to 60 feet. Caution must be used so as to not damage the well and screen.

Bailing - Although bailing is less effective than the surge block technique, the potential for well damage is minimal.

Surging by pumping - Recurrent pumping surges the well through cycles of drawdown and recovery. Generally air is used for pumping, however, which may change the chemistry of the ground water. Also, the procedure may be a potential source of contamination from lubricating oils. In shallow wells, a water-lubricated pump can be used for well development. This procedure has little effect on the chemistry of the ground water.

High velocity jetting - Either air or water in combination with air-lift pumping can be used to surge the well. The major benefit of this technique is that the jetting is done directly on the well screen. This method generally is regarded as one of the most effective well-development methods (Driscoll, 1986). However, the technique introduces air or water into the well and may change the chemistry of the ground water.

Indirect eduction jetting (IEJ) - An eduction line (rigid pipe or flexible tubing) about 1/2 the diameter of the well is placed to the depth of the center of the screen, and an air line is placed inside the eduction line about 1/3 the length of the static water column above the screen. Air is pumped to surge the well and the well discharges through the eduction line. The benefit of this technique is that air is not introduced into the aquifer. Therefore, the procedure has little effect on the chemistry of the ground water.

Brushing - Screens obstructed by sediment in shallow, small diameter wells can sometimes be dislodged by brushing. A long-handled brush with stiff bristles may be used to gently brush the screened interval.

Documentation

It is important to document the installation of wells. This documentation will include:

(1) Lithologic logs;

(2) Geophysical logs, as appropriate;

(3) Well construction diagram or equivalent field notes indicating depth, screen interval, and other important construction details;

(4) GWSI form and land-use and land-cover field sheet;

(5) Location - The location information should be cross-referenced with State identifications, U.S. Environmental Protection Agency identifications, and other location systems;

(6) Results of core analyses and hydraulic testing;

(7) Miscellaneous information--for example, bentonite lot numbers; and

(8) Photographs.

DETERMINATION OF HYDRAULIC PROPERTIES

Hydraulic properties of aquifers and confining units in the vicinity of wells can be estimated using several techniques: (1) interpretation of geophysical and lithologic logs, (2) hydraulic analysis of core samples, (3) estimates from measured specific capacities, (4) aquifer-test analysis, and (5) regional simulation of ground-water flow. Each method has an inherent range of uncertainty and certain benefits and limitations dependent on the level of complexity associated with the technique and the amount of data needed to accurately apply the technique.

The pilot projects will, in some cases, be determining hydraulic properties of aquifers and confining units in the vicinity of wells, but also will be using values determined by others. It is important to understand the limitations of various methods.

The least complex, but most uncertain, approach used to define hydraulic properties is to estimate them from lithologic or geophysical logs. This technique involves assigning a value of hydraulic conductivity based on a physical description of the aquifer material from lithologic logs or from an analysis of borehole geophysical logs. The method is explained in detail in Lohman (1972, p. 53). Values of hydraulic conductivity, porosity, and specific yield for selected rocks are given in Heath (1983) and Wolff (1982).

Hydraulic analysis of core samples can be used to define hydraulic properties. Limitations of this approach are that (1) the properties reflect only a small sample interval (the size of the core) and may not reflect an areally effective value for the hydrogeologic system, and (2) it is difficult to extract an undisturbed core that reflects *in situ* conditions. Numerous geotechnical laboratories routinely conduct tests to define hydraulic conductivity and compressibility. Freeze and Cherry (1979, p. 335-339) describe the laboratory tests commonly used to determine hydraulic properties.

Specific capacity data (the ratio of well discharge to drawdown) can be used to estimate hydraulic conductivity or transmissivity, but not storage properties. McClymonds and Franke (1972) and Hurr (1966) describe techniques for estimating transmissivity from specific capacity.

An aquifer test is a controlled field experiment specifically designed to determine the hydraulic properties of a hydrogeologic system. A test typically consists of observing water levels through space or time in response to a known hydraulic stress, generally the withdrawal of water from a well. A number of different analytical techniques can be used to analyze the aquifer-test data, dependent on the hydrogeologic setting and the design of the test. Single-well tests are used to define only hydraulic conductivity or transmissivity. An observation well usually is needed to accurately determine storage properties. Hydraulic properties determined from tests involving a pumping well and observation wells reflect a much greater areal sampling of the hydrogeologic system and, thus, are considered to be better estimates of properties that control areal ground-water flow. The U.S. Geological Survey (Office of Water Data Coordination, 1977) and Stallman (1971) describe procedures and recommended methods to design, conduct, and analyze the results of an aquifer test. Additional sources of information include Lohman (1972), Freeze and Cherry (1979), Reed (1980), and Heath (1983). Bennett and Rosenshein (1984) present a series of papers that reflect the state-of-the-art of ground-water hydraulics. Topics addressed include slug tests, pumping tests in fractured rock aquifers, and analysis of tests in a variety of hydrogeologic settings.

Most analytical techniques assume that the hydraulic properties are areally homogeneous. In some instances, the data (water levels from multiple observation wells distributed both vertically and areally) are available to determine the distribution of hydraulic properties in complex hydrogeologic systems. Numerical models of ground-water flow such as presented by Reilly (1984) and McDonald and Harbaugh (1988) can be used for this purpose.

In addition, reasonable estimates of hydraulic properties on a local scale sometimes can be derived from a regional analysis of ground-water flow. Ground-water flow models have been developed and calibrated for many areas. As part of the calibration process, the areal distribution of hydraulic properties of aquifers and confining units is estimated. Those values may be used, realizing the inherent limitations associated with the simulation scale of the particular areal model, to estimate local hydraulic properties.

WATER-QUALITY SAMPLING

Preparation

The following tasks should be completed before going to a site to sample:

(1) Obtain permission from the well owner to sample;

(2) Arrange access to the site;

(3) Complete site-descriptive information on field sheets and the National Water-Quality Laboratory analytical services request forms (see fig. 2) through record 3, except for the date and time of the sample;

(4) Clean pumps, delivery lines, and samplers; and

(5) Perform instrument maintenance and temperature calibrations on instruments.

Purging

Purging supplies aquifer water to the well by removing the water standing in the well casing. Before purging, the volume of water in the casing must be calculated (except for continuously operated production wells). In commonly used units, the volume is:

$$V = 0.0408HD^2$$

where V is the volume of water in the casing, in gallons;
D is the inside diameter of the casing, in inches; and
H is the length of the water column in the casing, in feet.

H is the difference between the depth to water and the depth of the well. If the water level in the well cannot be determined, the entire well depth will be used as the length of the water column. If possible, a static water-level measurement will be collected in accordance with established methods (Office of Water Data Coordination, 1977, p. 2-8).

Purging ideally should be done from the top of the water column to most efficiently eliminate standing water. This will not be possible in production wells with installed pumps. In observation wells, pumps having capacities per minute of at least 2 percent of the volume of water in the casing will be used. Smaller capacity pumps will be used only if the size of the well casing prohibits use of larger pumps. The pump intake initially will be placed below the static water level within the upper 10 percent of the total depth of water and lowered as needed to keep the intake submerged. If the well casing is entirely evacuated during purging, it will be allowed to recover sufficiently to collect a sample, or if recovery is not sufficient, the well will not be sampled.

The pumping rate and chemical stability of the discharge water will be monitored after purging is started. Flow meters can be used for monitoring pumping rate. Measuring the time required to fill a container of known volume also is adequate.

Special Handling (Circle as appropriate and explain in record 5)

Hazardous material

Field ID

Site Type (circle one)

SW - Surface Water
GW - Ground Water
ME - Meteorological
LK - Lake
ES - Estuary
SP - Spring
SS - Special Source

Station Name | Field Office | Project | Collector | Phone (FTS)

File Deposition*
(Circle one)
Q - WATSTORE
X - Lab File

For Laboratory Use Only

Record 1 — Sample identification

Station ID or Unique Number* | Project Account #

1 9
Year* | Month* | Day* | Time* — Begin Date

Month | Day | Time — Composite End Date

State Code* | District/ User Code* | County Code

Record 2 — Analysis level codes and schedules

Sample Medium** | Geologic Unit | H or 9 Analysis Status** | Analysis Source** | Hyrdologic Condition** | Sample Type** | Hydrologic Event**

Schedule #1 | Schedule #2 | Schedule #3 | Schedule #4 | Schedule #5

Record 3 — Laboratory codes to be added to (A) or deleted from (D) above schedules

Code	A/D	Code	A/D	Code	A/D	Code	A/D	Code	A/D	Code	A/D	Code	A/D	Code	A/D

Record 4 — Field values to be added to analysis.

WATSTORE/ Lab Code	Value	Rmk Code	QA Code	Meth Code	WATSTORE/ Lab Code	Value	Rmk Code	QA Code	Meth Code	WATSTORE/ Lab Code	Value	Rmk Code	QA Code	Meth Code
00027/ B3 Collecting Agency					82398/1201 Sampling Method Code					00061/ 61 Discharge, Instantaneous (cfs)				
72019/ 312 Depth to Water (BLS) (ft)					00020/ 65 Air Temperature (°C)					00010/ 64 Water Temperature (°C)				
00095/ 21 Specific Conductance (umhos)					00400/ 51 pH, Field					00025/1167 Barometric Pressure (mm Hg)				
00300/ 25 Dissolved Oxygen (mg/L)					00410/ 2 Alkalinity, Field (mg/L)					/				
/					/					/				

Records 5, 6 — Comments (limit to 138 characters)

Record 5

Record 6

Total number of sample bottles for this request: ________

* - Mandatory for acceptance for laboratory analysis
** - Mandatory for storage in WATSTORE

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Figure 2.--U.S. Geological Survey National Water-Quality Laboratory analytical services request form

Temperature, pH, dissolved oxygen (unless H_2S is present), and specific conductance will be monitored during purging. A flow-through chamber fitted with probes of field instruments normally will be used for making these measurements, if electrometric meters are used. The chamber must allow a relatively rapid exchange of water. Testing with dye is advisable to determine if any probes might be located in pockets of "dead" water. The dissolved-oxygen probe must be positioned so that a flow velocity of at least one foot per second continually passes it. Closed-top flow-through chambers are recommended so that probes are conveniently held in place and outflow water can be directed away from the work area. Because pressure can affect performance of some electrodes like pH, the outflow of closed-top chambers must be large enough to avoid back pressure, or the flow should be momentarily stopped when measuring parameters with pressure-sensitive probes. Accessory flow-through chambers that attach to the probe package are available for some multiparameter instruments. The probe package of a multiparameter instrument can be used in a simple cylinder having a bottom inflow and open top, but a stirring system will probably be needed to maintain sufficient flow velocity past the dissolved-oxygen probe.

If a flow-through chamber cannot be used, samples of the pump discharge can be collected periodically to make measurements. Samples for measurements sensitive to aeration, such as dissolved oxygen and pH, must be collected to avoid aeration.

Chemical stability is indicated when three successive measurements of the following three monitored parameters, taken at intervals of five minutes or more, differ by less than the following amounts:

Temperature------------------	0.2 degrees Celsius
Specific conductance---------	5 percent (or 5 microsiemens per centimeter [uS/cm] when less than 100 uS/cm)
pH---------------------------	0.1 unit

Wells will be considered successfully purged when the discharge water has chemically stabilized with regard to the three monitored parameters and a minimum of three casing volumes of water has been removed. If, however, chemical stability has not been attained after four casing volumes of water have been removed, sampling can be started if notes are made clearly describing the stabilization problem. Continuously operated production wells need to be purged only to chemical stability.

Sampler Selection

An important consideration when selecting a sampler is the change in water quality that may occur during the process of sampling. Changes may occur in both inorganic and organic constituents. A major concern is often associated with the degassing of volatile organic compounds and outgassing of carbon dioxide and other gases. To reduce cross contamination problems, the interchange of parts between sampling systems (such as pump discharge lines and suspension lines) will be avoided. The types of chemical analyses to be performed determine the kinds of devices that can be used for sampling.

Inorganic Constituents

Samplers that allow the sample to be aerated may cause changes in the concentrations of some inorganic constituents. Positive displacement pumps (including bladder pumps) and point-source (double valve) bailers with bottom-emptying devices are recommended samplers to avoid the introduction of air into the sample. Samples for inorganic constituents (including trace metals) should be allowed to contact only glass, Teflon, PVC, and stainless steel before being dis-charged into the sample container (Scalf and others, 1981; Barcelona and others, 1984). Polyethylene materials are not recommended for discharge lines because they tend to adsorb trace metals (Eichholz and others, 1965).

Organic Constituents

Positive-displacement pumps and point-source bailers having bottom-emptying devices are recommended samplers because they have been demonstrated to recover the greatest amount of purgeable organic compounds from water (Imbrigiotta and others, 1988). Samples for organic constituents should be allowed to contact only glass, Teflon, and stainless steel to minimize effects of adsorption or leaching (Pettyjohn and others, 1981; Curran and Thompson, 1983; and Barcelona and others, 1984). Because new materials may leach substances, all new materials will be cleaned before being used.

Descriptions of Recommended Samplers

The bladder pump is a noncontact, gas-driven pump that can be constructed completely of Teflon and Teflon-coated materials. It uses compressed gas to alternately expand and contract a flexible bladder to force successive pump volumes past a check valve and up through a discharge line. This pump produces a noncontinuous flow.

The helical rotor submersible pump employs an electric motor to turn a helical stainless steel rotor against a semiflexible stator to create a progressing-cavity pumping head. This pump is capable of delivering a continuous stream of water. The samples contact only the stator and stainless steel and Teflon surfaces in the pump.

The gear submersible pump has a set of meshing Teflon gears that form the basis of the pumping system. The gears, driven by an electric motor, act as paddle wheels which push the water along the internal pump walls from the intake point to the pump discharge. The close tolerance of the Teflon gears prevents water from passing back between them. The sample contacts only the stainless steel pump body, the Teflon gears, and discharge tubing.

The point-source bailer is constructed entirely of Teflon and consists of a cylinder with two one-way valves. A one-way valve on the bottom allows water to pass through as it travels downward. After the bailer is lowered to the desired sampling depth, the direction of travel is reversed and a slug of water is retained by the one-way valve. A second one-way valve is positioned at the top of the bailer barrel. The top one-way valve effectively seals off the sample in the bailer as it is retrieved. This prevents exchange with water higher in the well, reduces the potential for degassing of volatile organic compounds during upward travel, and prevents contamination of the sample with particulates scraped from the well casing. The top one-way valve is dislodged with a small rod to allow displacement of the sample with air during sample transfer using a bottom-emptying device.

Collecting Samples from Wells

Water-quality constituents to be included in sample analyses for all three ground-water pilot projects are listed in table 7, along with their

Geological Survey laboratory code or schedule number (Feltz and others, 1985). The water-quality constituents in table 7 represent laboratory analyses. Field measurements of pH, specific conductance, alkalinity, dissolved oxygen, and temperature also will be made.

After the purging of observation wells, the sampling device will be lowered to just above the well screen or just above the bottom of the casing in open hole wells. In many cases, the pump used for purging can be used to collect samples and thus will be in place.

General sample collection, treatment, and preservation procedures are shown in table 8. These procedures conform to the requirements of the U.S. Geological Survey National Water-Quality Laboratory (Feltz and others, 1985). The NAWQA schedule numbers shown in table 8 refer to schedules for the NAWQA Program that were created to simplify the completion of laboratory analytical services request forms. For some wells, not all of the constituents referred to in table 8 will be analyzed.

Samples will be collected in a specific order. The suggested order for filling sample bottles is in the order in which the constituent classes are listed in table 8. Nutrient samples should be the last filtered inorganic samples collected to ensure maximum flushing of surfactants (which interfere with phosphorous analyses) from the filter. To avoid potential problems of mercury contamination, the mercuric chloride ampoules used to preserve the nutrient samples should be added only after the sample collection and handling of other inorganic samples is complete. For temperature, pH, specific conductance, dissolved oxygen, and other parameters monitored during purging, the last recorded values before sample collection will be reported as sample measurements. Alkalinity will be done in the field by incremental titration.

Field Notes

Complete field notes will be made to record results of instrument calibrations, parameter values during purging, and measurements made during alkalinity titrations. When appropriate, additional observations will address problems experienced with chemical stabilization, sediment, degassing, pre cipitates, odors, and other relevant factors, including observations about the sampling site that may be important for interpretation of potential contamination problems, such as recent application of pesticides, exhaust vapors from the pump generator, and so forth.

Storage and Shipping of Water Samples

All samples will be packaged according to the instructions provided by the U.S. Geological Survey National Water-Quality Laboratory. Most samples will be packed in ice to reduce geochemical and biological processes. Only samples designated for inorganic constituents (except nutrients) and isotopes can remain unchilled. All samples, except those to be stored for future analyses, such as for stable isotopes and tritium, will be shipped promptly (by air mail or overnight air express, if necessary) to the laboratory--in most cases on the day of collection and always within 4 days of collection. This should allow ample time for sample preparation and analysis so that the maximum holding times recommended by the U.S. Environmental Protection Agency will not be exceeded. The samples will be sent to the laboratory in heavy-

Table 7.--*Water-quality constituents to be included in laboratory analyses for all three ground-water pilot projects, National Water-Quality Assessment Program*

Constituent(s)	Laboratory code (LC) or schedule number (SH)
Properties and major constituents	
pH	LC0068
Specific conductance	LC0069
Alkalinity	LC0070
Calcium	SH1043
Magnesium	SH1043
Potassium	LC0054
Sodium	SH1043
Chloride	LC1213
Fluoride	SH1043
Sulfate	LC1200
Silica	SH1043
Nutrients	
Ammonia	LC0301
Nitrite	LC0160
Nitrite and nitrate	LC0228
Kjeldahl nitrogen (ammonia plus organic nitrogen)	LC0268
Soluble reactive phosphorus	LC0162
Major metals and trace elements	
Antimony	LC0077
Arsenic	LC0112
Barium	SH1043
Beryllium	SH1043
Boron	SH1043
Cadmium	SH1043
Chromium	SH1043
Cobalt	SH1043
Copper	SH1043
Iron	SH1043
Lead	SH1043
Lithium	SH1043
Manganese	SH1043
Mercury	LC0226
Molybdenum	SH1043
Nickel	SH1043
Selenium	LC0087
Silver	SH1043
Strontium	SH1043
Vanadium	SH1043
Zinc	SH1043

Table 7.--*Water-quality constituents to be included in laboratory analyses for all three ground-water pilot projects, National Water-Quality Assessment Program--Continued*

Constituent(s)	Laboratory code (LC) or schedule number (SH)
	Radionuclides
Gross alpha	SH0456 or SH0458[2]
Gross beta	SH0456 or SH0458[2]
Radon-222	LC1369
Tritium[1]	LC0624 or LC1043[3]
	Organic compounds
Dissolved organic carbon	LC0113
Volatile organic compounds	SH1380
Carbamate insecticides	SH1359
Chlorophenoxy-acid herbicides	SH0079
Nitrogen-containing pesticides (largely triazine herbicides)	SH1389
	Stable isotope ratios
Deuterium/protium[1]	LC0300
Oxygen-18/oxygen-16[1]	LC0489

[1]Samples should be collected and stored at project office for possible analysis later.

[2]Use SH0456 if estimated concentration of dissolved solids is less than 250 mg/L and SH0458 otherwise.

[3]Appropriate laboratory method depends on use of data (Robert Michel, U.S. Geological Survey, written commun., 1988).

Table 8.--*General ground-water sample collection, treatment, and preservation procedures for the pilot National Water-Quality Assessment (NAWQA) Program*

Constituent class	NAWQA schedule number	Regular laboratory codes (LC) or schedule numbers (SH)	Sample collection procedure	Size and type of container(s)	Treatment and preservation
pH, specific conductance, and alkalinity	SH0457	LC0068 LC0069 LC0070	Fill bottles directly from pump discharge line or bailer.	250 mL polyethylene bottle, field rinsed	None.
Major constituents, major metals, and trace elements	SH0457	SH1043 LC1213 LC0054 LC0070 LC0077 LC0087 LC0112 LC0226 LC1200	From pump: install in-line filter and fill bottles downstream of the filters. Plate-type acrylic or polycarbonate filter units using membrane filters (0.45µ pore size) should normally be used. The filters must be flushed with at least 200 mL of sample before samples are collected. For heavy sediment loads, disposable in-line cartridges may be used, after flushing with 700 mL of sample. For bailer: composite samples in non-metallic container and use peristaltic pump to force water through filter. Fill bottles downstream of filter after flushing as described above.	500 mL polyethylene bottle, acid rinsed 250 mL polyethylene bottle, field rinsed 250 mL glass bottle, acid rinsed	Acidify with HNO_3 to pH<2. None Acidify with 1 $HNO_3/K_2Cr_2O_7$ ampoule.
Gross radioactivity	-	SH0456 or [1]SH0458	Same procedure as above.	Two 1-L polyethylene bottles, field rinsed	Acidify with HNO_3 to pH<2.
Nutrients	SH0455	LC0160 LC0162 LC0228 LC0268 LC0301	Same procedure as above.	250 mL brown polyethylene bottle, field rinsed	Add 1 ampoule $HgCl_2/NaCl$ solution, chill and maintain at 4°C.

Table 8.--*General ground-water sample collection, treatment, and preservation procedures for the pilot National Water-Quality Assessment (NAWQA) Program--Continued*

Constituent class	NAWQA schedule number	Regular laboratory codes (LC) or schedule numbers (SH)	Sample collection procedure	Size and type of container(s)	Treatment and preservation
Stable isotope ratios	-	LC0300 LC0489	Same procedure as above. Leave very little air space in bottles.	125 mL glass bottle	Use polyseal cap and (or) seal with wax or plastic tape.
Dissolved organic carbon	-	LC0113	Put discharge from pump or bailer in stainless steel filter unit with silver membrane filter and use compressed nitrogen or air pressure from a peristaltic pump to force sample through filter into sample bottle.	125 mL glass bottle	Bottle baked at 350°C by National Water-Quality Laboratory, chill and maintain at 4°C.
Tritium	-	LC0624 or [2]LC1043	Fill bottles directly from pump discharge line or bailer. Leave very little air space in bottle.	1 L glass bottle	Untreated. Use polyseal cap and (or) seal with wax or plastic tape. Do not store near radium (e.g., glowing clocks, watches, signs, etc.).

Table 8.--*General ground-water sample collection, treatment, and preservation procedures for the pilot National Water-Quality Assessment (NAWQA) Program--Continued*

Constituent class	NAWQA schedule number	Regular laboratory codes (LC) or schedule numbers (SH)	Sample collection procedure	Size and type of container(s)	Treatment and preservation
Volatile organic compounds	[3]SH1380	-	Samples must be collected to avoid aeration: (1) Insert discharge line from the pump or bailer to the bottom of the sample vial (the discharge line should be metal or teflon). (2) Add 2 drops of reagent grade HCl (1:1) to bottom of sample vial and fill to just overflowing. (Alternately, HCl may be injected just below water surface, after filling the vial.) (3) Slowly withdraw the discharging line from the bottle, leaving a convex meniscus at the mouth. (4) Replace bottle cap immediately. The Teflon (white) side of the septum should contact the sample. Do not let samples degas before replacing cap. (5) Invert the bottle and check for gas bubbles. If gas bubbles are present, discard and resample. If degassing of samples makes avoiding bubbles impossible, notes should be made to this effect in both the field notes and on the laboratory analytical services request form. Give an estimate of the relative volume of bubble(s) in the sample.	Three 40 mL glass septum vials (numbered in order filled)	Two drops of 1:1 HCl. If residual chlorine present, add sodium thiosulfate crystals. Protect sample from sunlight, chill and maintain at 4°C.

Table 8.--*General ground-water sample collection, treatment, and preservation procedures for the pilot National Water-Quality Assessment (NAWQA) Program--Continued*

Constituent class	NAWQA schedule number	Regular laboratory codes (LC) or schedule numbers (SH)	Sample collection procedure	Size and type of container(s)	Treatment and preservation
Pesticides	-	SH0079 SH1359 SH1389	Fill bottles directly from pump discharge line or bailer.	Four 1 L glass bottles (use one bottle as spare)	Bottles baked at 350°C by National Water-Quality Laboratory. Chill samples and maintain at 4°C.
Radon-222	-	LC1369	Collect duplicate samples directly from pump discharge in syringe and inject into glass vials containing liquid-scintillation solution.	Two glass vials containing liquid-scintillation solution	Inject 10 mL of sample below liquid-scintillation solution.

[1]Use SH0456 if estimated concentration of dissolved solids is less than 250 mg/L and SH0458 otherwise.

[2]Appropriate laboratory method depends on use of data (Robert Michel, U.S. Geological Survey, written communication, 1988).

[3]SH1380 is a special NAWQA schedule that is the same as SH1391 in Feltz and others (1985) but includes additional volatile organic compounds.

duty coolers. Samples for organic analyses will be collected and sent to avoid the warming of coolers over nonwork days. Samples that require chilling and that are retained for the weekend will be kept at or below 4°C, but will not be allowed to freeze. A 250-mL bottle of water labeled "Temperature" will be included with each cooler. The National Water-Quality Laboratory Log-In office will return reply cards (or reply sheets) indicating the date that samples were received and the temperature of the water in the "Temperature" bottle. The reply cards will be franked and pre-addressed by the project office or reply sheets enclosed with self-addressed envelopes. Any samples containing hazardous materials or requiring special handling will be clearly marked and the laboratory will be notified in advance that such samples have been sent.

Equipment Cleaning

The outside and inside of pumps and sampling equipment will be rinsed with clean tap water or, preferably, with deionized water after each site is sampled. After 5 uses, or when contamination from the previous sampling site is suspected, the equipment will be washed in a warm solution of general purpose, phosphate-free laboratory detergent prior to rinsing with tap water, followed by a final rinse with deionized water. New equipment also will be cleaned in this manner to avoid leaching of materials into the samples. Cleaned samplers to be used for collecting inorganic constituents will be stored in clean plastic bags. Cleaned samplers for organic constituents will be stored in aluminum foil.

If contamination is encountered during sampling, pumps and equipment may have to be cleaned with solvents or discarded. Specific needs will have to be determined on a case-by-case basis. Any solvents used must be completely rinsed from the equipment. Wash-blank samples can be analyzed to ensure this.

Project-Submitted Quality-Assurance Samples

Quality-assurance samples are collected and submitted to determine the integrity of the sampling results. In particular, these samples are submitted to evaluate potential problems with field conditions, sampling procedures, storage and shipping practices, laboratory methods, and analyst performance, depending on the type and source of the quality-assurance sample. Procedures to test the laboratory methods and the analyst performance are conducted by the U.S. Geological Survey National Water-Quality Laboratory. Each project will submit quality-assurance samples to evaluate the other potential problems. Overall, these project-submitted quality-assurance samples will total approximately an additional 10-15 percent of all samples collected for each study. The kinds of quality-assurance samples to be included are:

Trip blanks - These blanks are used mainly to monitor potential contamination during shipping and storage by diffusion of volatile organic compounds through the septum of the sample bottle. Samples of high-purity laboratory water are bottled under clean conditions in the U.S. Geological Survey National Water-Quality Laboratory. These blanks are sent with empty bottles to each project and remain with other samples through the sampling trip and subsequent analyses, but are not opened in the field.

Field and equipment blanks - These samples consist of high-purity water filled under field conditions, including filtration and addition of preservatives, as appropriate. (For wells sampled with project pumps, this should include running the water through the pumping system.)

Duplicates - These are duplicate water samples that should be bottled in immediate succession.

Spikes - These are water samples containing a measured amount of constituent(s) added at the sampling site.

Duplicate spikes - These are duplicate water samples each containing the same amount of measured constituent(s) added at the site. (Thus, a duplicate spike is two spiked samples submitted in addition to a regular, unspiked sample.)

Reference samples - These samples consist of water containing known quantities of one or more constituents added under controlled laboratory conditions. (Many of the reference samples referred to here are natural water samples spiked in a laboratory. A large number of reference samples are analyzed from a single batch by the U.S. Geological Survey to obtain a statistically reliable estimate of the constituent concentrations.)

The distribution of the type and number of quality-assurance samples will not be equal among the different types of analyses because (1) some types of samples require more comprehensive quality assurance than others, (2) different types of samples may be affected by different conditions, and (3) quality-assurance materials (such as referenced samples) are not available for all sample types. Table 9 shows a suggested overall distribution of quality-assurance samples for the pilot project studies. The number of blanks shown in table 9 refers to field and equipment blanks for all constituents except volatile organic compounds for which trip blanks also are included.

Additional quality assurance targeted at particular locations and (or) at selected constituents may be necessary to uncover problems detected by this quality-assurance program or to further validate key findings in particular pilot project areas. This more intensive quality assurance may utilize additional types of quality-assurance samples. For example, spiked field blanks together with spiked samples may be used to investigate suspected sample-matrix interference effects associated with a particular water type, location, and (or) chemical constituent.

Some additional recommendations in conducting field quality assurance are:

(1) Select wells ahead of time for quality-assurance sampling to help assure good coverage of various field conditions.

(2) Intensify quality assurance when there are significant changes in sample collection procedures, including equipment changes.

(3) Conduct the different types of quality assurance for a particular constituent class at the same sampling sites to help in interpretation of the results.

Table 9.--*Suggested overall distribution of quality-assurance samples submitted by the ground-water pilot projects to the National Water-Quality Laboratory*

[Numbers represent percent of total samples for each type]

Type	Blanks	Duplicates or triplicates	Duplicate spikes	Reference samples
Major and minor ions and nutrients	2	5		*
Dissolved organic carbon	2	10		
Gross radioactivity		10**		
Radon		100***		
Pesticides	5		10	
Volatile organic compounds	5-10		5-10	

*The USGS Branch of Quality Assurance routinely submits reference samples for inorganic analyses through the Double Blind Sample Program. These comprise about 3-4 percent of the samples submitted to the National Water-Quality Laboratory. The results of these analyses, summarized over the previous 6-month period, are available on a monthly basis.

**The National Water-Quality Laboratory routinely performs this type of quality assurance on about 10 percent of the samples received. Therefore, a duplicate sample should be submitted for about 1 out of every 10 samples submitted for gross alpha and gross beta analysis. Label as "Use for Lab Duplicate." Send in a single log-in sheet for both samples, and write at the bottom, under the Remarks section, a note that a duplicate sample has been included. The laboratory will submit most of these extra samples as duplicates or spikes and report the results to the project.

***The standard laboratory protocol for radon calls for analyses of duplicate samples submitted by the projects.

SUMMARY

Several pilot projects are being conducted as part of the National Water-Quality Assessment (NAWQA) Program. The purpose of the pilot program is to test and refine concepts for a proposed full-scale program. Three of the pilot projects are specifically designed to assess ground water.

The purpose of this report is to describe the criteria that are being used in the NAWQA pilot projects for selecting and documenting wells, installing new wells, and sampling wells for different water-quality constituents. The report was prepared specifically for the NAWQA pilot projects and is not intended to be a general purpose field manual.

Guidelines are presented for the selection of wells for sampling. Information needed to accurately document each well includes site characteristics related to the location of the well, land use near the well, and important well construction features. These guidelines ensure the consistency of the information collected and will provide comparable data for interpretive purposes.

Guidelines for the installation of wells are presented and include procedures that need to be followed for preparations prior to drilling, the selection of the drilling technique and casing type, the grouting procedure, and the well-development technique. Information needed to adequately document the installation of these wells is presented.

A major component of the protocols is related to water-quality sampling. Tasks are identified that need to be completed prior to visiting the site for sampling. Guidelines are presented for purging the well prior to sampling, both in terms of the volume of water pumped and the chemical stability of field parameters. Guidelines are presented concerning sampler selection as related to both inorganic and organic constituents. Documentation needed to describe the measurements and observations related to sampling each well and treating and preserving the samples are also presented.

Procedures are presented for the storage and shipping of water samples, equipment cleaning, and quality assurance. Quality-assurance guidelines include the description of the general distribution of the various quality-assurance samples (blanks, spikes, duplicates, and reference samples) that will be used in the pilot program.

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