Techniques of Water-Resources Investigations

Book 9
Handbooks for Water-Resources Investigations

National Field Manual for the Collection of Water-Quality Data

Chapter A1.
PREPARATIONS FOR WATER SAMPLING

By
Franceska D. Wilde, Dean B. Radtke, Jacob Gibs, and Rick T. Iwatsubo

USGS
science for a changing world

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, ***Secretary***

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, ***Acting Director***

For additional information write to:

Chief, Office of Water Quality
U.S. Geological Survey
12201 Sunrise Valley Drive
Mail Stop 412
Reston, VA 20192
ISBN = 0-607-90623-5

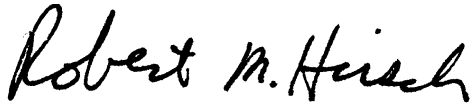
Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286, Federal Center
Denver, CO 80225

Foreword

The mission of the Water Resources Division 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 and scientific agencies, and the general public. Reliable and objective 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 data collected are of the quality required to fulfill our mission.



Robert M. Hirsch
Chief Hydrologist

Techniques of Water-Resources Investigations

Book 9
Handbooks for Water-Resources Investigations

Chapters of Section A: National Field Manual for the Collection of Water-Quality Data[1]

---

[1]**Bold type indicates published chapters and chapter sections, and shaded type indicates chapters and chapter sections that are in preparation.**

PREPARATIONS FOR WATER SAMPLING

National Field Manual for the Collection of Water-Quality Data

Chapter A1.

Illustrations

Tables

Chapter A1. PREPARATIONS FOR WATER SAMPLING

By **Franceska D. Wilde, Dean B. Radtke, Jacob Gibs, and Rick T. Iwatsubo**

ABSTRACT

The *National Field Manual for the Collection of Water-Quality Data* (*National Field Manual*) describes protocols and provides guidelines for U.S. Geological Survey (USGS) personnel who collect data used to assess the quality of the Nation's surface-water and ground-water resources. This chapter addresses field-trip preparations, including selection of sample-collection sites for studies of surface-water quality, site reconnaissance and well selection for studies of ground-water quality, and the establishment of electronic files and field files for a sampling site.

Each chapter of the *National Field Manual* will be published separately and revised periodically. Newly published and revised chapters will be announced on the USGS Home Page on the World Wide Web under "New Publications of the U.S. Geological Survey." The URL for this page is <http://water.usgs.gov/lookup/get?newpubs>.

INTRODUCTION

As part of its mission, the U.S. Geological Survey (USGS) collects data needed to assess the quality of our Nation's water resources. The *National Field Manual for the Collection of Water-Quality Data (National Field Manual)* describes protocols (requirements and recommendations) and provides guidelines for USGS personnel who collect water-quality data. Chapter A1 addresses preparations for collecting water samples at surface-water and ground-water sites. Formal training and field apprenticeship are needed in order to correctly implement the protocols and guidelines described in this manual.

The *National Field Manual* is Section A of Book 9 of the USGS publication series "Techniques of Water-Resources Investigations" and consists of individually published chapters. Chapter numbers are preceded by an "A" to indicate that the report is part of the *National Field Manual*. Chapters of the *National Field Manual* are referred to in the text by the abbreviation "NFM" followed by the chapter number (or chapter and section number). For example, NFM 4 refers to Chapter 4 on "Collection of Water Samples." NFM 4.1 refers to the section on surface-water sampling methods.

PURPOSE AND SCOPE

The *National Field Manual* is targeted specifically toward field personnel in order to (1) establish and communicate scientifically sound methods and procedures, (2) provide methods that minimize data bias and, when properly applied, result in data that are reproducible within acceptable limits of variability, (3) encourage consistent use of field methods for the purpose of producing nationally comparable data, and (4) provide citable documentation for USGS water-quality data-collection protocols.

This chapter of the *National Field Manual* informs field personnel of the major steps needed to prepare for water-quality data-collection activities, select surface-water sampling sites, make reconnaissance visits to ground-water sampling sites and select wells that will meet scientific objectives, and set up electronic and paper files. Study design and data-network design are beyond the scope of this publication. This chapter is not a tutorial on statistical methods of site selection and does not address well installation.

REQUIREMENTS AND RECOMMENDATIONS

As used in the *National Field Manual* the terms "required" and "recommended" have the following USGS-specific meanings:

Required (require, required, or requirements) pertains to USGS protocols and indicates that USGS Office of Water Quality policy has been established on the basis of research and (or) consensus of the technical staff and has been reviewed by water-quality specialists and selected District[1] or other professional personnel, as appropriate. Technical memorandums or other internal documents that define the policy pertinent to such requirements are cited in this publication. Personnel are instructed to use required equipment or procedures as described herein. Departure from or modifications to the stipulated requirements that might be necessary to accomplishing specific data-quality requirements or study objectives must be quality assured and documented.

Recommended (recommend, recommended, recommendation) pertains to USGS protocols and indicates that USGS Office of Water Quality policy recognizes one or several acceptable alternatives to a given procedure or equipment selection on the basis of research and (or) consensus. References to technical memorandums and selected publications pertinent to such recommendations are cited in this publication to the extent that such documents are available. Specific data-quality requirements, study objectives, or other constraints may affect the choice of recommended equipment or procedures. Selection from among the recommended alternatives should be based on referenced research and good field judgment, and reasons for the selection must be documented. Departure from or modifications to recommended procedures must be quality assured and documented.

FIELD MANUAL REVIEW AND REVISION

Chapters of the *National Field Manual* will be reviewed, revised, and reissued periodically to incorporate technical advances, correct any errors, and address additional topics. Comments or corrections can be sent to NFM-QW, USGS, 412 National Center, Reston, VA 20192 (or send electronic mail to nfm-owq@usgs.gov). Newly published and revised chapters will be announced on the USGS Home Page on the World Wide Web under "New Publications of the U.S. Geological Survey." The URL for this page is <http://water.usgs.gov/lookup/get?newpubs>.

[1]"District" refers to an organizational unit of the USGS, Water Resources Division, in any of the States or territories of the United States.

ACKNOWLEDGMENTS

The information included in the *National Field Manual* is based on existing manuals, various reference documents, and a broad spectrum of colleague expertise. In addition to the references provided, important source materials include unpublished USGS training and field manuals and technical memorandums. The authors wish to acknowledge the following individuals in the USGS who developed the field and training manuals that provided the foundation for this *National Field Manual*: M.E. Dorsey, T.K. Edwards, W.B. Garrett, W.J. Gibbons, R.T. Kirkland, L.R. Kister, J.R. Knapton, M.T. Koterba, C.E. Lamb, W.W. Lapham, R.F. Middelburg, Jr., J. Rawson, L.R. Shelton, M.A. Sylvester, and F.C. Wells.

The authors are indebted to the following colleagues for reviews that improved the technical quality of this report: B.A. Bernard, R.W. Boulger, J.O. Brunett, T.K. Edwards, G.D. Glysson, J.R. Gray, M.A. Hardy, R.L. Rickman, S.K. Sando, R.L. Snyder, and Y.E. Stoker. Valuable editorial assistance was provided by I.M. Collies, C.M. Eberle, B.B. Palcsak, and Chester Zenone. Production assistance from L.S. Rogers, C.T. Mendelsohn, L.E. Menoyo, and A.M. Weaver was instrumental in maintaining the quality of this report.

The editors wish to thank and pay tribute to R.W. Lee and S.W. McKenzie, who were responsible for final technical review, and who contributed to the accuracy, quality, and usability of this report.

Special thanks go to T.L. Miller, whose encouragement and faith in this project has been instrumental to its achievement; and to D.A. Rickert, for providing the support needed to produce a national field manual for water-quality studies.

PREPARATIONS FOR WATER SAMPLING A1.

By **Franceska D. Wilde, Dean B. Radtke, Jacob Gibs, and Rick T. Iwatsubo**

This chapter of the *National Field Manual for the Collection of Water-Quality Data* provides guidelines for field personnel as they prepare to select and (or) evaluate surface-water and ground-water sampling sites, establish site files, and prepare for sample-collection field trips.

FIELD-PERSONNEL RESPONSIBILITIES 1.0

Before sample collection begins, field personnel must take steps to ensure that the samples collected will be representative of the aqueous system being investigated. A representative water sample is a sample that typifies ("represents") that part of the aqueous system to be studied and is delineated by the objectives and scope of the study. USGS data-collection efforts often take a whole-system approach, meaning that data-collection methods ensure representation of an entire stream reach or aquifer volume. A modified approach is needed for studies in which samples are representative of a specific part or aspect of an aqueous system instead of the entire system; for example, a study of aquatic ecology may establish nearshore boundaries on the system, and an oil-spill study may target only the surface of a water-table aquifer within a designated boundary or circumference.

- Be alert to sample representativeness. The data are no better than the confidence that can be placed in how well the sample represents the aqueous system (Feltz and Culbertson, 1972).
- Plan to collect quality-control samples. Quality-control checks applied during laboratory analyses of the samples cannot compensate for data that are biased because samples were not representative of the aqueous system or because samples were improperly collected and processed.

Field personnel are also responsible for providing the necessary information to establish USGS National Water Information System (NWIS)[2] site files for each sampling site and for checking to see that the site file is functional, that the information it contains is correct, and that updates are made promptly.

Update files promptly:

- The Ground-Water Site Inventory (GWSI) file contains site information.
- The Quality-of-Water Data (QWDATA) file contains field and laboratory data.
- The Automatic Data Processing System (ADAPS) file contains time-series information.

[2]National Water Information System (NWIS) is the hydrologic data base for the U.S. Geological Survey. Updated versions are released periodically.

FIELD-TRIP PREPARATIONS 1.1

All details of a field trip need to be planned well in advance. Adequate time must be scheduled in the workplan to review data requirements and make field-trip preparations—a common mistake is to put off these activities until the last minute.

Before selecting sites or making other preparations:

- Understand the purpose for which the various types of data will be collected and the aqueous system that each sample should represent.
- Review the study workplan, especially types of measurements and samples needed.
- Make field reconnaissance trips before selecting sampling sites, if possible.
  - Note conditions that could affect sampling operations (such as the seasonal high or low streamflow, flowing wells, or site-access peculiarities).
  - Evaluate potential sources of contamination at the site, based on target analytes[3] to be collected.
- Review site files and field folders. (Note site location, description and access, and review any previously collected physical, chemical, and biological data.)
- Obtain and keep current with training and the laboratory requirements associated with your data-collection activities.

[3]"Target analyte" refers to any chemical or biological substance for which concentrations in a sample will be determined. Target analyte does not include field-measured properties such as temperature, specific electrical conductance (conductivity), dissolved-oxygen concentration, pH, Eh, alkalinity, color, or turbidity. The *Concise Chemical and Technical Dictionary,* 4th edition (Bennett, 1986) defines "analyte" as "Substance being determined in an analysis."

Before selecting equipment:

Understand the physical and chemical limitations of each piece of equipment, in order to meet data-collection objectives and data-quality requirements[4] (refer to NFM 2). Verify and test, if possible, the operational range of the sampling equipment to be used.

Before starting field work:

- Review site files and update and review the field folder for each site from which samples and ancillary data will be collected (see sections 1.2.2 and 1.3.2).
- Review the safety plan and be sure that you have the training needed if you will be working at sites designated as hazardous (see NFM 9).

Plan ahead! Take adequate time to prepare.

1.1.1 CHECKLISTS OF EQUIPMENT, SUPPLIES, AND ACTIVITIES

Each study needs to establish and follow a protocol for data-collection activities. Checklists help ensure that equipment and supplies will be ordered on time, that data-collection activities will be completed appropriately, and that data-quality requirements will be met (fig. 1-1). Most checklists are generic to all projects and sites (for example, vehicle and equipment maintenance checklists), but may need to be customized (for example, items listed, quantities of equipment and supplies, number of batteries, and types of sample bottles and other equipment). The types of information and examples of items listed on the next page are usually included when developing checklists.

[4]As used in this publication, the term "data-quality requirements" refers to that subset of data-quality objectives pertaining specifically to the analytical detection level for concentrations of target analytes and the allowable variability to fulfill the scientific objectives of the study.

Types of information	Examples of items or activities in checklists
Calendar of planned field trips	Prepare calendars/checklists that include sampling dates, members of field team, vehicle(s) to be used.
Presampling activities	Prepare checklists; for example, field-trip preparations checklist (fig. 1-1) and well-information checklist (fig. 1-3).
Postsampling activities	Update field folders and computer files. Log in samples (Analytical Services Request form). Store and dispose of hazardous materials properly. Check that all equipment is clean and properly stored.
Field equipment and supplies	Prepare lists of equipment/supplies for each field site (see NFM 2). Prepare a list of items to be ordered.
Equipment/supplies maintenance and testing	Prepare a checklist of maintenance/testing for field-measurement instruments (see NFM 6). Test sample-collection and processing equipment. Charge or replace batteries.
Vehicle maintenance	Check fluids, battery, tires, lights, cleanliness.
Sample-collection, -processing, -shipping, and -documentation information and supplies	Prepare headers on forms (such as field, chain-of-custody, and Analytical Services Request forms); prepare bottle labels. Prepare lists of chemical constituents, with analytical schedules, methods, laboratory codes; bottle type and volume; sample handling, treatment, and preservation procedures; shipment; quality-control samples.
Field-folder contents	Prepare list of logistical information needed for each site, such as permission to access site, keys, maps.
Safety equipment and information	Keep a copy of NFM 9 for field use and list special considerations for the site, such as personal flotation devices.

FIELD-TRIP PREPARATIONS

PROJECT: _____SITES: _____DATE:_____

✓	Prefield activity	Comments
	Order supplies	Ordered 3 cases Ultrex for site #2 Completed on _____ , by _____ .
	Prepare deionized water (in-house system) Check prior laboratory analysis	Last change of cartridges, on _____ Last chemical analysis on _____ , by _____ , Conductivity checks out , by _____
	Check expiration dates on reagents	Need _____ conductivity standard(s) Need pH _____ buffer(s)
	Clean and test equipment	Completed on _____ , by _____ Problems _____
	Collect equipment blanks	Completed on _____ , by _____ Results reviewed by _____ (District water-quality specialist or project chief)
	Clean sample bottles	Completed on _____ , by _____
	Label sample bottles, prepare field forms	Completed on _____ , by _____
	Obtain permission for site access	Completed on _____ , by _____
	Check field vehicle for safety equipment and supplies, such as material safety data sheets, flares, and remote communications system (NFM 9)	Completed on _____ , by _____
	Charge/replace batteries	Completed by _____
	Update field folder	Completed by _____
	Make travel reservations, arrangements	Completed by _____
	Provide supervisor with field-trip and call-in (check-in) schedule	Provided on _____ to _____
	Other	

Figure 1-1. Example of a presampling activities checklist.

DATA-QUALITY PLANS AND PREPARATIONS 1.1.2

USGS policy that water-quality data be of a defined and documented quality is described in Horowitz and others (1994) and Office of Water Quality Technical Memorandum 93.11 (see "Selected References and Internal Documents"). Every study should have a written document that describes study objectives, data-quality requirements, and a quality-assurance plan. Some of the information needed to ensure data quality is described in District quality-assurance plans. Discipline specialists (District and Regional specialists, discipline offices at USGS headquarters in Reston, Va., and USGS National Research Program scientists) can provide specific instructions and updates relating to quality-assurance procedures and policies for the collection of water-quality, surface-water, and ground-water data.

Field personnel are responsible for determining whether the equipment and methods being used could impair sample quality. For the most part, this determination involves collecting quality-control samples and analyzing the results. Field personnel must plan and prepare for routine checks on data quality.

- Examine field and laboratory results as soon as possible, preferably before the next sample-collection field trip. Results indicating potential bias in the data will alert you to the changes needed in equipment, equipment-cleaning procedures, or field methods used.
- Be prepared to collect additional blanks, replicates, or other field quality-control samples, based on your judgment of the effects of field conditions on sample collection. Field conditions are unpredictable, and adverse or unexpected conditions could necessitate additional steps to document data quality.

Quality-control samples are collected either in the office laboratory or at the field site, depending on their specific purpose (see NFM 3, "Cleaning of Equipment for Water Sampling," NFM 4, "Collection of Water Samples," and NFM 5, "Processing of Water Samples"). Field personnel must be familiar with the various types of quality-control samples and know how and when to collect them in order to comply with USGS quality-assurance requirements. Collection of blank samples (blanks) is mandatory. Blanks are samples of laboratory-prepared and -analyzed water that are processed through the equipment in the same manner as the environmental sample, but after the equipment has been cleaned and prepared for field use.

In preparation for collection of quality-control samples, solutions of the appropriate type and quality must be obtained for blank and standard reference material samples. Field personnel should use water for blank samples that is certified by the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. Laboratory certification should indicate that the blank water has target-analyte concentrations that are less than the method-detection limits. Blank water for determination of inorganic constituents needs to be the inorganic blank water obtained from the Quality of Water Service Unit in Ocala, Fla.; blanks for analysis of organic compounds require either pesticide blank water or volatile/pesticide blank water, both of which can be obtained from NWQL. Standard/reference materials generally are obtained from the National Institute of Standards and Technology.

Blank water for determination of inorganic constituents needs to be inorganic blank water. Blanks for analysis of organic compounds require either pesticide blank water or VOC/pesticide (Universal) blank water. All are available from the USGS "One-Stop Shopping."

- Collect equipment blanks before beginning the field effort.
  - Equipment blanks are processed through clean equipment in the controlled setting of an office laboratory.
  - Process an equipment blank at least once a year for each set of sample-contacting equipment. This applies to new equipment to be used for the first time, to equipment that will be cleaned with a new cleaning procedure, and to equipment that has not been tested with an equipment blank for 1 year.
  - Do not collect or process environmental samples until the annual equipment blank data have been reviewed. The field personnel or the water-quality specialist needs to ensure that the equipment blanks are either free of contamination or have concentrations small enough to be insignificant at the current analytical limits (Horowitz and others, 1994).
- Collect field blanks at the field site under the same conditions as environmental samples. Field blanks can provide information on the efficacy of the equipment cleaning procedures used and on ambient atmospheric contamination.

Data quality begins before the first sample is collected—be aware of data-quality requirements and potential sources of contamination.

Blank page

SURFACE WATER 1.2

Before sample collection, sampling sites must be selected (section 1.2.1). For each sampling site, NWIS files and a field folder must be established, updated, and reviewed (section 1.2.2).

- The study team is responsible for selecting sampling sites and conditions (such as time of year, flow rate or stage) that will yield samples representative of the aqueous system being studied.
  - Each body of flowing and still surface water has a unique set of conditions that needs to be identified and considered in the site-selection process.
  - Field personnel must be trained in the correct and current water-quality data-collection procedures and must exercise judgment gained from field experience in order to make appropriate site selections.
- The study team is responsible for establishing and maintaining files for each sampling site.
  - Careful and complete documentation of site information and data collected must be input to electronic and paper files.
  - The field folder must include all the information necessary for efficient field operations.

SELECTION OF SAMPLING SITES 1.2.1

Once field work has begun, field personnel must select the point(s) or transect(s) at which samples will be collected. In most bodies of flowing or still water, a single sampling site or point is not adequate to describe the sampling area's physical properties and the distribution and abundance of chemical constituents or biological communities. Location, distribution, and number of surface-water sampling sites can affect the quality of resulting data. Generic guidelines for selecting flowing-water and still-water sites are described in this section.

When selecting surface-water sampling sites:

- Safety of field personnel comes first.
- Consider the study objectives, types of data needed, equipment needs, and sampling methods.
- Obtain all available historical information.
- Consider physical characteristics of the area, such as size and shape, land use, tributary and runoff characteristics, geology, point and nonpoint sources of contamination, hydraulic conditions, climate, water depth, and fluvial-sediment transport characteristics.
- Consider chemical and biological characteristics of the area (aquatic and terrestrial).

1.2.1.A Flowing-Water Sites

Flowing-water sites refer to streams (fast or slow, intermittent, ephemeral, or perennial), canals, ditches, and flumes of all sizes and shapes, or to any other surface feature in which water moves unidirectionally. All or parts of reservoirs and estuaries that flow unidirectionally are considered to be flowing water. Global-positioning system (GPS) equipment is useful to identify sampling-site location. Determine latitude and longitude from maps or by land-survey techniques.

Flowing-water sampling sites optimally are located:

- At or near a stream-gaging station, to obtain concurrent surface-water discharge data required for computing constituent-transport loads and to determine discharge/constituent-concentration relations. (Measure discharge at time of sampling if a stream-gaging station is not at or near the sampling site or if discharge cannot be rated or estimated with sufficient accuracy.)
- In straight reaches with uniform flow, with a uniform and stable bottom contour, and where constituents are mixed along the cross section.

- Far enough above and below confluences of streamflow or point sources of contamination to avoid sampling a cross section where flows are poorly mixed or not unidirectional.
- In reaches upstream from bridges or other structures, to avoid contamination from the structure or from a road surface.
- In unidirectional flow that does not include eddies. (If eddies are present within the channel, sample only the unidirectional flow.)
- At or near a transect in a reach where other data are collected (such as data for suspended sediment, bedload, bottom material, or biological material) and (or) for which historical data are available.
- At a cross section where samples can be collected at any stage throughout the period of study, if possible.

After a tentative selection of a sampling site, develop a preliminary profile of field measurements[5] at various locations along the cross section (NFM 4 and NFM 6). The field-measurement profile is used to indicate reach homogeneity (see TECHNICAL NOTE). Final site selection is based on a comparison of these field measurements with the data requirements of the study.

TECHNICAL NOTE: The preferred sampling method and number of verticals to be sampled within the stream cross section that are needed to obtain a sample that is sufficiently representative depends on stream homogeneity as indicated by the field-measurement profile and stream-discharge or other data, as well as by study objectives. Sampling methods are described in NFM 4. Note that the field-measurement profile is a useful guideline, but might not be representative of chemical homogeneity for the analytes of interest. Also, it might be desirable to move to a sampling site upstream or downstream to adjust for seasonal variation or extreme flow conditions.

[5]Field-measurement methods are described in NFM 6. The profile of the cross section usually includes measurements such as specific electrical conductance (conductivity), pH, temperature, dissolved oxygen, and turbidity.

The guidelines used for selecting sampling sites on ephemeral and intermittent streams are the same as those for perennial streams. Ephemeral and intermittent stream sites need additional planning and examination to account, for example, for conditions related to rapidly changing stage and discharge that can occur as a result of flash flooding or urban runoff.

CAUTION: Any stream, including an ephemeral or intermittent stream, can rapidly become too deep and swift to wade safely.

1.2.1.B Still-Water Sites

Still-water sites refer to all sizes and shapes of lakes, reservoirs, ponds, swamps, marshes, riverine backwaters, or any other body of surface water where water generally does not move unidirectionally. All or parts of reservoirs that do not flow unidirectionally could be considered to be still water.

When locating still-water sampling sites:

- Use in situ field measurements to help determine vertical and spatial distribution of sampling locations.
- Avoid areas near structures such as harbors, boat ramps, piers, fuel docks, and moored houseboats (to avoid point sources of contamination), unless these structures are part of the study.
- Select sites with a record of historical data, if possible.

INFORMATION FOR NATIONAL WATER INFORMATION SYSTEM (NWIS) FILES AND FIELD FOLDERS 1.2.2

Field personnel are responsible for establishing and maintaining electronic and paper site files. The information required for establishing electronic records in NWIS and for creating field folders for surface-water sampling sites is summarized below.

NWIS Files 1.2.2.A

USGS policy requires specific information on surface-water sampling sites to be stored in the site file in NWIS (Edwards and others, 1987; Hubbard, 1992; WRD Memorandum 92.59). Results of water analyses are stored in the water-quality file (QWDATA) of NWIS. The Automatic Data Processing System (ADAPS) contains continuous records of water levels and water quality. The minimum information required for establishing electronic files in NWIS for surface water is listed in table 1-1. Individual studies and District offices may have additional data-storage requirements.

If the site location has been identified:

- Establish or check the NWIS site file before the field trip.
- Update the files promptly after the field trip.
- Fill in information that is needed by, or could be useful to, the study in addition to the information shown on table 1-1.

RULE OF THUMB:

Before starting fieldwork—Make sure the NWIS file is established.

After fieldwork—Input updates to NWIS files promptly.

Table 1-1. Minimum information required for electronic storage of site and surface-water-quality data in the U.S. Geological Survey (USGS) National Water Information System (NWIS)

[GWSI, Ground-Water Site Inventory; QWDATA, Quality of Water Data]

Information required for creation of a surface-water site in NWIS[1, 2]		
Data description	Component (C) number for data entry into GWSI	Example (Description of code)
Agency code	C4	USGS
Station Identification Number	C1	11530500
Station Name	C12	Klamath River near Klamath, Cal.
Latitude	C9	413052
Longitude	C10	1235957
District/User	C6	06 (California)
State	C7	06 (California)
County	C8	015 (Del Norte)
Agency Use	C803	A (Active)
Station Type	C802	SW
Information required for storage of sample analyses in the water-quality file of NWIS (QWDATA)[1]		
Data description	Alpha parameter code	Sample data (Description of code)
Agency code	AGNCY	USGS
Station Identification Number	STAID	11530500
Sample Medium	MEDIM	9 (surface water)
Sample Type	STYPE	9 (regular sample)
Hydrologic ("Hydro") Event	EVENT	9 (routine sample)
Hydrologic ("Hydro") Condition	HSTAT	9 (stable stage)
Date (year/month/day)	DATES	19880909
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 NWIS that can be useful for data analysis or mandatory for meeting study objectives; for example, indicating whether a non-USGS agency collected the data.
[2]Modified from Ground-Water Site Schedule Form 9-1904-A, May 1991. Also refer to Mathey (1991) and Garcia and others (1997).

1.2.2.B Field Folders

Selected information that is needed for reference while at a surface-water site is kept in a field folder. The field folder contains information needed by trained personnel to locate and safely collect and process water samples. The field folder is taken along on each sampling trip. General contents of the field folder are listed on the field-folder checklist (fig. 1-2), but the folder should be customized according to study needs.

Field-folder checklist: surface-water quality		
✓	Item	Comments
	Station description: • Location of gaging station (if one is present). • Location of sample-collection sites: high and low streamflows. • Hydrologic and geologic sections. • Name of landowner, tenant, or other responsible party. • Site access instructions (for example, call owner or site operator before arrival at site, obtain key to unlock security gate). • Photographs to document site conditions.	
	Maps to site (State and local)	
	Profiles of cross section of stream channel at sampling location(s). • Stream-bottom geometry. • Physical and chemical measurements.	
	Safety information (NFM 9): • Nearest emergency facilities. • Phone numbers (home) of study chief or supervisor. • Traffic condition and traffic plan showing where to park, placement of flags and cones. • Location of power lines. • Environmental hazards, such as weather and animals.	
	Sampling schedule: • Laboratory analyses to be requested and associated codes. • When to collect samples (high or low flow).	
	Bottle types needed for each analytical schedule.	
	Analytical Services Request form(s) and example of a completed form.	
	Sampling instructions: • Cumulative-discharge curves at about 10-, 50-, and 90-percent duration. • Velocity cross sections at about 10-, 50-, and 90-percent duration. • Equipment to use at various flows. • Flow-duration curve. • Discharge rating curves and (or) tables.	
	Shipping instructions: • Amount of ice to use. • Mailing labels to and from laboratory. • Location of nearest post office or shipping agent.	
	Surface-water field form and an example of completed form.	
	A tabulation sheet for each type of bacteria enumerated at the site (include example with date of sample, streamflow, volumes filtered, dilutions, plate counts).	
	Plots of field-measured data (last 5-10 years of record); if there is a good enough relation to show outliers, include: • Conductivity versus streamflow. • Conductivity versus alkalinity. • Temperature versus time.	
	Statistical summary of historical water data: • Seasonal, maximum-minimum values. • Discharge-related maximum-minimum values.	
	Special equipment needed to address site-specific conditions: • Sampling. • Safety.	

Figure 1-2. Checklist for contents of surface-water-sampling field folder.

Blank page

GROUND WATER 1.3

Ground water is sampled from various types of existing wells or wells installed specifically for a study.

- Water-supply wells are wells that are installed primarily for supply of public, irrigation, domestic, commercial, or industrial water and usually are equipped with a dedicated high-capacity pump. The term "supply well" is used in this publication.
- 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).
- Monitor wells are observation wells that are installed specifically for assessment of physical, chemical, and biological characteristics of the aquifer. Low-capacity portable pumps are commonly used for sampling, but monitoring wells can be equipped with a dedicated pump. The term "monitoring well" is used in this publication.

Information is compiled about the well and well site during site-reconnaissance visits, well installation, and subsequent data-collection efforts at the site. This information is used to help select the well(s) needed for study. The ground-water site inventory is compiled in the office and verified in the field. In an office inventory, the study team identifies existing wells or well sites and compiles background information and available records for those wells. The field inventory is completed during reconnaissance trips in which well location is verified, additional information is collected, and the suitability of the site for study objectives is determined. For each well, the inventory of site and well information is entered into the NWIS water-quality (QWDATA) and ground-water site inventory (GWSI) data bases and is added to the file created for the well (well file).

1.3.1 SITE RECONNAISSANCE AND WELL SELECTION

Field personnel critically evaluate existing and installed wells to determine whether they will yield samples that are representative of the environment targeted for study.

As a member of the study team:

- Be prepared to participate in office- and field-related aspects of selecting and installing wells (see Lapham and others, 1997, for details).
- Be familiar with study objectives and requirements for data collection and quality.
- Be familiar with considerations for well selection and well installation (summarized in table 1-2).

Information gathered from a site reconnaissance visit can help determine whether an existing well or a proposed well-installation site meets the criteria established by the study. Site reconnaissance visits also ensure efficient field operations and could be a critical factor in site selection or rejection. These site visits commonly are needed to verify the location and condition of wells, evaluate site characteristics, and make modifications to the site and adjustments to sampling plans to allow sampling to proceed. Before leaving for the site, determine the activities that are to be completed and make the necessary preparations (table 1-3).

Keep in mind the primary concerns for water-quality studies:

- The sample must represent the system intended for study.
- Sample integrity must be maintained.

Site visits also can be 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, and identify the presence of target analytes.

Review safety plans and procedures before leaving for the field.

Table 1-2. 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.
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 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). • 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 water treatments, pressure tanks, or holding tanks.

Table 1-3. Example of site-reconnaissance activities

Before the site visit
Review considerations for well selection and installation (summarized in table 1-2).
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 well by field personnel. (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
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 • 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 data on the appropriate form(s).
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.
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 a portable pump or another intended sampling device is suitable for use.

Table 1-3. Example of site-reconnaissance activities—*Continued*

During the site visit—***Continued***
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 the hydraulic 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 connected 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, time consuming, and 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.

1.3.2 INFORMATION FOR NATIONAL WATER INFORMATION SYSTEM (NWIS) FILES, WELL FILES, AND FIELD FOLDERS

USGS policy requires specific information on ground-water sampling sites to be stored in NWIS (Edwards and others, 1987; Hubbard, 1992; WRD Memorandum 92.59). Paper documents, such as agreements between the well owner and the USGS for use of the well, also are necessary and are stored in well files and field folders.

- 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 that will be needed to set up well files for new wells is recorded by field personnel as the new well is installed (Lapham and others, 1997).

RULE OF THUMB:

Before starting fieldwork—Make sure the NWIS file is established.

After fieldwork—Update NWIS files promptly.

NWIS Files 1.3.2.A

Within the NWIS system, well information, ground-water levels, and water-quality data are stored in three data bases: the Ground-Water Site Inventory (GWSI), Quality of Water Data (QWDATA), and the Automatic Data Processing System (ADAPS). All wells for which data are stored must be identified by an electronic record in NWIS.

- GWSI primarily contains (1) descriptive information about the site and well and (2) noncontinuous water-level data. Specific information entered into GWSI is used to create an NWIS site file.
- QWDATA contains results of water-quality analyses, noncontinuous water-level data, and other data related to water-quality analysis.
- ADAPS contains continuous records of water levels and water quality.

The minimum information required for establishing electronic files in GWSI and QWDATA is shown in table 1-4. Individual studies and District offices may have additional data-storage requirements. For example, the GUNIT (geologic unit) code provides important information for ground-water studies.

When creating or updating a GWSI site-file record, fill in information that is needed by, or useful to, the study, in addition to the required information shown in table 1-4.

Table 1-4. Minimum information required for electronic storage of site and ground-water-quality data in the U.S. Geological Survey National Water Information System (NWIS)

[GWSI, Ground-Water Site Inventory; QWDATA, Quality of Water Data]

Information required for creation of a ground-water file 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
Station locator sequence number	C815	01
District/User	C6	24 (Maryland)
State	C7	10 (Delaware)
County	C8	003 (Sussex)
Agency Use	C803	A (Active)
Station Type	C802	6 (Well)
Data Reliability	C3	C (Field Checked)
Site Type	C2	W (Well)
Use of site	C23	O (Observation)
Information required for storage of sample analyses in the water-quality file of NWIS (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	19880909
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 from those shown are available in NWIS and QWDATA that can be useful for data analysis or mandatory for meeting study objectives; for example, indicating whether a non-USGS agency collected the data.

[2]From Ground-Water Site Schedule Form 9-1904-A, May 1991. Also refer to Mathey (1991) and Garcia and others (1997).

Well Files 1.3.2.B

A well file also must be established for each well selected or installed for the study or in a data network. At the outset of the study, it is useful to refer to a checklist of the items and types of information needed for the well file (fig. 1-3).

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.

- Include well-construction information to the extent that it is available (Lapham and others, 1997).
- Include water-quality information, hydrogeologic field forms and logs, and plots of water-quality data and other hydrologic, geologic, geochemical, or geophysical information available for the well or field site.
- Include a log of well-maintenance and well-integrity checks and tests, geophysical logs and surveys, results of aquifer tests, analyses of cores or cuttings of geologic materials, and analyses from previously collected samples from the well or from a nearby well.

Field Folders 1.3.2.C

Selected information related to the well file and electronic records is kept in a field folder. The field folder contains information needed by personnel to locate and gain access to the site and to collect and process ground-water samples. The field folder should be taken along on each visit to the well for reference at the field site. The generic contents of a field folder are listed in the field folder checklist (fig. 1-4). Examples of site-location maps and a site sketch are shown in figure 1-5.

WELL-INFORMATION CHECKLIST, Page 1 of 2

Project name and identification number: _____
Latitude-longitude: _____ Sequence number: _____
Other site or well ID: _____ Station name: _____

Indicate well type: Public, Domestic, Commercial, Industrial, Irrigation, Observation, Monitoring, Other _____

Item in well file	Date item filed
Criteria for well selection or installation	_____
Ground-Water Site Inventory (GWSI) data entered into National Water Information System (NWIS)	_____
Paper copy of GWSI form	_____
Copies of agreement to complete activity (for example, drilling or sampling) _____	_____
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 and method of determination	_____
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 1-3. Example of a well-information checklist for a well file and field folder.

WELL-INFORMATION 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)	_____
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 _____

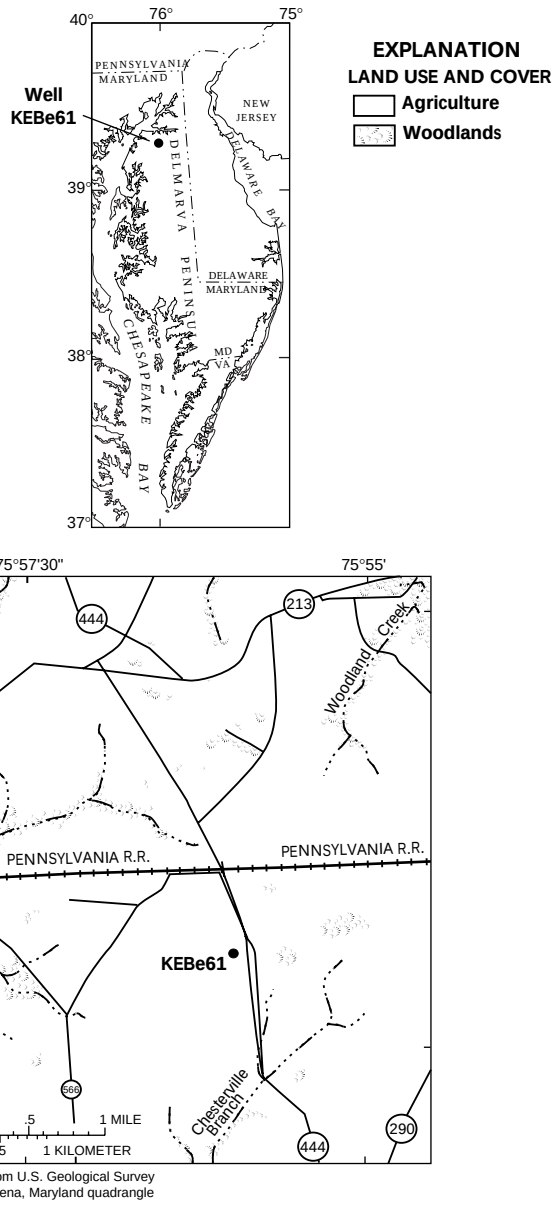
Other information (for example, geologic unit, aquifer name):

Figure 1-3. Example of a well-information checklist for a well file and field folder—*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.	
	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.	
	Sampling schedule and instructions: • Laboratory analyses, codes, and bottle types. • Preservation requirements. • 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. • Place to discharge excess water.	
	Water-level measurements: • Location of measuring point. • Previous records from well.	
	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.	
	Ancillary information: • Geologic section(s). • Hydrologic section(s). • Borehole geophysical logs.	
	Shipping instructions: • Mailing labels; location of nearest post office or shipping agent. • Ice or holding time requirements.	

Figure 1-4. Checklist for contents of ground-water-sampling field folder

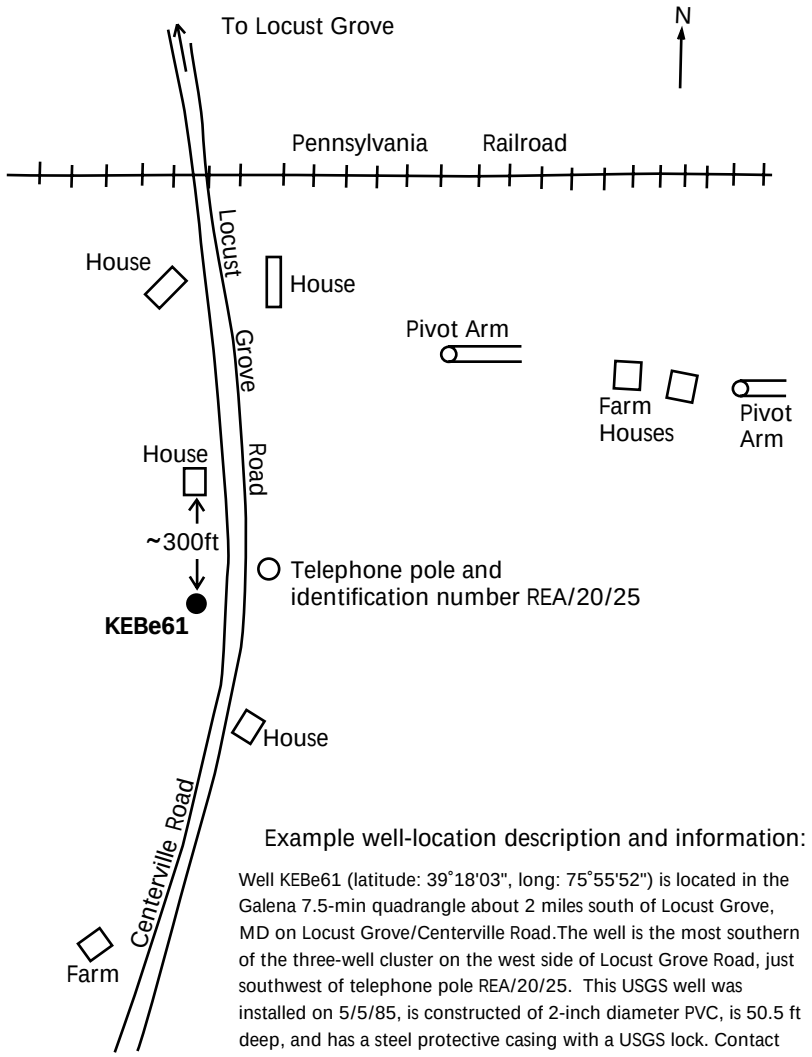
Example location map(s):



A.

Figure 1-5. Example of (*A*) site- and well-location maps and (*B*) well-site sketch with well-site information.

Example of site sketch:



Example well-location description and information:

Well KEBe61 (latitude: 39˚18'03", long: 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 ( )___-____ the day before sampling.

B.

Figure 1-5. Example of (*A*) site- and well-location maps and (*B*) well-site sketch with well-site information—*Continued*.

SELECTED REFERENCES AND INTERNAL DOCUMENTS

SELECTED REFERENCES FOR PREPARATIONS FOR WATER SAMPLING

American Public Health Association, American Water Works Association, and Water Environment Federation, 1992, Standard methods for the examination of water and wastewater (18th ed.): Washington, D.C., American Public Health Association, variously paged.

Bennett, H., ed., 1986, Concise chemical and technical dictionary (4th ed.): New York, Chemical Publishing Co., p. 99.

California Department of Water Resources, 1994, Guidelines for preparing quality assurance project plans: State of California, The Resource Agency, Quality Assurance Technical Documentation 6, 40 p.

Dempster, G.R., Jr., compiler [1990], National water information system user's manual--volume 2, chapter 3. Automated data processing system: U.S. Geological Survey Open-File Report 90-116, version 90.1, variously paged.

Edwards, M.D., Putnam, A.L., and Hutchison, N.E., 1987, Conceptual design for the National Water Information System: U.S. Geological Survey Bulletin 1792, 22 p.

Edwards, T.K., and Glysson, G.D., 1998, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water Resources Investigations, book 3, chap. C2, 80 p.

Feltz, H.R., and Culbertson, J.K, 1972, Summary procedures and problems in determining pesticide residues in the hydrologic environment: Pesticides Monitoring Journal, v. 6, no. 3, p. 171-178.

Garcia, K.T., Maddy, D.V., Lopp, L.E., Coupe, R.H., Jr., and Schertz, T.L., 1997, User's manual for the national water information system of the U.S. Geological Survey Chapter 2—Water-quality system: U.S. Geological Survey Open-File Report 97-634, 253 p.

Gy, Pierre., 1979, Sampling of particulate materials—theory and practice: New York, Elsevier, 431 p.

Horowitz, A.J., Demas, C.R. Fitzgerald, K.K., Miller, T.L., and Rickert, D.A., 1994, U.S. Geological Survey protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water: U.S. Geological Survey Open-File Report 94-539, 57 p.

Hubbard, E.F., 1992, Policy recommendations for management and retention of hydrologic data of the U.S. Geological Survey: U.S. Geological Survey Open-File Report 92-56, 32 p.

Jones, D.A., Gurney, R.J., and O'Connell, P.E., 1979, Network design using optimal estimation procedures: Water Resources Research, v. 15, no. 6, p. 1801-1812.

Keith, L.H., 1988, Principles of environmental sampling: Washington, D.C., American Chemical Society, 458 p.

Keith, L.H., ed., 1991, Compilation of EPA's sampling and analysis methods: Chelsea, Mich., Lewis Publishers, 803 p.

Keith, S.J., Wilson, L.G., Fitch, H.R., and Esposito, D.M., 1983, Sources of spatial-temporal variability in ground-water quality data and methods of control: Ground Water Monitoring Review, v. 3, no. 2, p. 21-32.

Kittrell, F.W., 1969, A practical guide to water quality studies of streams: Washington, D.C., U.S. Federal Water Pollution Control Administration, 135 p.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program—Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.

Lapham, W.W., Wilde, F.D., and Koterba, M.T., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program—selection, installation, and documentation of wells, and collection of related data: U.S. Geological Survey Open-File Report 95-398, 69 p.

_____1997, Guidelines and standard procedures for studies of ground-water quality—selection and installation of wells, and supporting documentation: U.S. Geological Survey Water-Resources Investigations Report 96-4233, 110 p.

Mathey, S.B., compiler [1990], National water information system user's manual, volume 2, chapter 5. Water-use data system—part 1. Site-specific water-use data system (SSWUDS): U.S. Geological Survey Open-File Report 90-198, version 90.2, variously paged.

Mathey, S.B., ed., 1991, System requirements specification for the U.S. Geological Survey's National Water Information System II: U.S. Geological Survey Open-File Report 91-525, 622 p.

Miller, James, ed., 2002, Ground water atlas of the United States, accessed November 29, 2002, at http://capp.water.usgs.gov/gwa/index.htm

Natrella, M.G., 1966, Experimental statistics: Washington, D.C., U.S. Department of Commerce, National Bureau of Standards Handbook 91, p. 2-9 to 2-11.

Norris, J., 1988, Techniques for sampling surface and industrial waters—Special considerations and choices, *in* Keith, L.H., ed., Principles of environmental sampling, Washington, D.C., American Chemical Society, p. 247-253.

Plumb, R., Jr., 1981, Procedures for handling and chemical analysis of sediment and water samples: Vicksburg, Miss., Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Technical Report EPA/CE-81-1, p. 3-73 —3-76.

Pritt, J.W., and Raese, J.W., 1995, Quality assurance/quality control manual—National Water Quality Laboratory: U.S. Geological Survey Open-File Report 95-443, 35 p.

Schmidt, K.D., 1982, How representative are water samples collected from wells? *in* Proceedings of Second National Symposium on Aquifer Restoration and Groundwater Monitoring, National Water Well Association, Columbus, Ohio, p. 117-128.

Shelton, L.R., 1994, Field guide for collecting and processing stream-water samples for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-455, 42 p.

U.S. Environmental Protection Agency, 1980, Samplers and sampling procedures for hazardous waste stream: EPA 600/ 2-80-018, 70 p.

_____1982a, Sampling protocols for collecting surface water, bed sediment, bivalves, and fish for priority pollutant analysis: Washington, D.C., Final Draft Report, Office of Water Regulations and Standards Monitoring and Data Support Division, from chap. A2: EPA 68-01-6195, variously paged.

U.S. Environmental Protection Agency, 1982b, Handbook for sampling and sample preservation of water and wastewater: Cincinnati, Ohio, Environment Monitoring and Support Laboratory, EPA 600/4-82-029, 402 p.

_____1987, A compendium of superfund field operations methods: Washington, DC., Office of Emergency and Remedial Response, EPA/540-P-87/001, 508 p.

U.S. Geological Survey, 1980, Ground water, chap. 2 *in* U.S. Geological Survey, National handbook of recommended methods for water-data acquisition: p. 2-1 to 2-149.

_____1984, Chemical and physical quality of water and sediment, chap. 5 *in* U.S. Geological Survey, National handbook of recommended methods for water-data acquisition: p. 5-1 to 5-194.

Ward, J.R., and Harr, C.A., eds., 1990, Methods for collection and processing of surface-water and bed-material samples for physical and chemical analyses: U.S. Geological Survey Open-File Report 90-140, 71 p.

Wells, F.C., Gibbons, W.J., and Dorsey, M.E., 1990, Guidelines for collection and field analysis of water-quality samples from streams in Texas: U.S. Geological Survey Open-File Report 90-127, 79 p.

INTERNAL DOCUMENTS

Office of Water Quality and Water Resources Division numbered memorandums are available electronically on the Internet through the USGS Home Page on the World Wide Web. The site address (URL) is http://water.usgs.gov/lookup/get?searchmemo

Memo number	Title	Date
	Office of Water Quality	
qw 93.11	PROGRAMS AND PLANS: Implementation of the Protocol for Collecting and Processing Surface-Water Samples for Low-Level Inorganic Analyses	July 15, 1993
	Water Resources Division	
wrd 92.59	Policy for Management and Retention of Hydrologic Data of the U.S. Geological Survey	October 20, 1992

Blank page

PUBLICATIONS ON TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS

The U.S. Geological Survey publishes a series of manuals describing procedures for planning and conducting specialized work in water-resources investigations. The material is grouped under major subject headings called books and is further divided into sections and chapters. For example, Section A of Book 9 (Handbooks for Water-Resources Investigations) pertains to collection of water-quality data. The chapter, which is the unit of publication, is limited to a narrow field of subject matter. This format permits flexibility in revision and publication as the need arises.

The Techniques of Water-Resources Investigations (TWRI) reports listed below are for sale by the U.S. Geological Survey, Branch of Information Services, Box 25286, Federal Center, Denver, CO 80225 (authorized agent of the Superintendent of Documents, Government Printing Office). Prepayment is required. Remittance should be sent by check or money order payable to the U.S. Geological Survey. Prices are not included because they are subject to change. Current prices can be obtained by writing to the above address. When ordering or inquiring about prices for any of these publications, please give the title, book number, chapter number, and "U.S. Geological Survey Techniques of Water-Resources Investigations." An updated list of TWRI reports can be found on the World Wide Web. The URL for this page is http://water.usgs.gov/lookup/get?TWRI.

Book 1. Collection of Water Data by Direct Measurement

Section D. Water Quality

1–D1.Water temperature—influential factors, field measurement, and data presentation, by H.H. Stevens, Jr., J.F. Ficke, and G.F. Smoot: USGS—TWRI Book 1, Chapter D1. 1975. 65 pages.

1–D2.Guidelines for collection and field analysis of ground-water samples for selected unstable constituents, by W.W. Wood: USGS—TWRI Book 1, Chapter D2. 1976. 24 pages.

Book 2. Collection of Environmental Data

Section D. Surface Geophysical Methods

2–D1.Application of surface geophysics to ground-water investigations, by A.A.R. Zohdy, G.P. Eaton, and D.R. Mabey: USGS—TWRI Book 2, Chapter D1. 1974. 116 pages.

2–D2.Application of seismic-refraction techniques to hydrologic studies, by F.P. Haeni: USGS—TWRI Book 2, Chapter D2. 1988. 86 pages.

Section E. Subsurface Geophysical Methods

2–E1.Application of borehole geophysics to water-resources investigations, by W.S. Keys and L.M. MacCary: USGS—TWRI Book 2, Chapter E1. 1971. 126 pages.

2–E2.Borehole geophysics applied to ground-water investigations, by W.S. Keys: USGS—TWRI Book 2, Chapter E2. 1990. 150 pages.

Section F. Drilling and Sampling Methods

2–F1.Application of drilling, coring, and sampling techniques to test holes and wells, by Eugene Shuter and W.E. Teasdale: USGS—TWRI Book 2, Chapter F1. 1989. 97 pages.

Book 3. Applications of Hydraulics

Section A. Surface-Water Techniques

3–A1.General field and office procedures for indirect discharge measurements, by M.A. Benson and Tate Dalrymple: USGS—TWRI Book 3, Chapter A1. 1967. 30 pages.

3–A2.Measurement of peak discharge by the slope-area method, by Tate Dalrymple and M.A. Benson: USGS—TWRI Book 3, Chapter A2. 1967. 12 pages.

3–A3.Measurement of peak discharge at culverts by indirect methods, by G.L. Bodhaine: USGS—TWRI Book 3, Chapter A3. 1968. 60 pages.

3–A4.Measurement of peak discharge at width contractions by indirect methods, by H.F. Matthai: USGS—TWRI Book 3, Chapter A4. 1967. 44 pages.

3–A5.Measurement of peak discharge at dams by indirect methods, by Harry Hulsing: USGS—TWRI Book 3, Chapter A5. 1967. 29 pages.

3–A6.General procedure for gaging streams, by R.W. Carter and Jacob Davidian: USGS—TWRI Book 3, Chapter A6. 1968. 13 pages.

3–A7.Stage measurement at gaging stations, by T.J. Buchanan and W.P. Somers: USGS—TWRI Book 3, Chapter A7. 1968. 28 pages.

3–A8.Discharge measurements at gaging stations, by T.J. Buchanan and W.P. Somers: USGS—TWRI Book 3, Chapter A8. 1969. 65 pages.

3–A9.Measurement of time of travel in streams by dye tracing, by F.A. Kilpatrick and J.F. Wilson, Jr.: USGS—TWRI Book 3, Chapter A9. 1989. 27 pages.

3–Al0.Discharge ratings at gaging stations, by E.J. Kennedy: USGS—TWRI Book 3, Chapter A10. 1984. 59 pages.

3–A11.Measurement of discharge by the moving-boat method, by G.F. Smoot and C.E. Novak: USGS—TWRI Book 3, Chapter A11. 1969. 22 pages.

3–A12.Fluorometric procedures for dye tracing, Revised, by J.F. Wilson, Jr., E.D. Cobb, and F.A. Kilpatrick: USGS—TWRI Book 3, Chapter A12. 1986. 34 pages.

3–A13.Computation of continuous records of streamflow, by E.J. Kennedy: USGS—TWRI Book 3, Chapter A13. 1983. 53 pages.

3–A14.Use of flumes in measuring discharge, by F.A. Kilpatrick and V.R. Schneider: USGS—TWRI Book 3, Chapter A14. 1983. 46 pages.

3–A15.Computation of water-surface profiles in open channels, by Jacob Davidian: USGS—TWRI Book 3, Chapter A15. 1984. 48 pages.

3–A16.Measurement of discharge using tracers, by F.A. Kilpatrick and E.D. Cobb: USGS—TWRI Book 3, Chapter A16. 1985. 52 pages.

3–A17.Acoustic velocity meter systems, by Antonius Laenen: USGS—TWRI Book 3, Chapter A17. 1985. 38 pages.

3–A18.Determination of stream reaeration coefficients by use of tracers, by F.A. Kilpatrick, R.E. Rathbun, Nobuhiro Yotsukura, G.W. Parker, and L.L. DeLong: USGS—TWRI Book 3, Chapter A18. 1989. 52 pages.

3–A19.Levels at streamflow gaging stations, by E.J. Kennedy: USGS—TWRI Book 3, Chapter A19. 1990. 31 pages.

3–A20.Simulation of soluble waste transport and buildup in surface waters using tracers, by F.A. Kilpatrick: USGS—TWRI Book 3, Chapter A20. 1993. 38 pages.

3–A21.Stream-gaging cableways, by C. Russell Wagner: USGS—TWRI Book 3, Chapter A21. 1995. 56 pages.

Section B. Ground-Water Techniques

3–B1. Aquifer-test design, observation, and data analysis, by R.W. Stallman: USGS—TWRI Book 3, Chapter B1. 1971. 26 pages.

3–B2.Introduction to ground-water hydraulics, a programed text for self-instruction, by G.D. Bennett: USGS—TWRI Book 3, Chapter B2. 1976. 172 pages.

3–B3.Type curves for selected problems of flow to wells in confined aquifers, by J.E. Reed: USGS—TWRI Book 3, Chapter B3. 1980. 106 pages.

3–B4.Regression modeling of ground-water flow, by R.L. Cooley and R.L. Naff: USGS—TWRI Book 3, Chapter B4. 1990. 232 pages.

3–B4.Supplement 1. Regression modeling of ground-water flow—Modifications to the computer code for nonlinear regression solution of steady-state ground-water flow problems, by R.L. Cooley: USGS—TWRI Book 3, Chapter B4. 1993. 8 pages.

3–B5.Definition of boundary and initial conditions in the analysis of saturated ground-water flow systems—An introduction, by O. L. Franke, T.E. Reilly, and G.D. Bennett: USGS—TWRI Book 3, Chapter B5. 1987. 15 pages.

3–B6.The principle of superposition and its application in ground-water hydraulics, by T.E. Reilly, O.L. Franke, and G.D. Bennett: USGS—TWRI Book 3, Chapter B6. 1987. 28 pages.

3–B7.Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow, by E.J. Wexler: USGS—TWRI Book 3, Chapter B7. 1992. 190 pages.

Section C. Sedimentation and Erosion Techniques

3–C1.Fluvial sediment concepts, by H. P. Guy: USGS—TWRI Book 3, Chapter C1. 1970. 55 pages.

3–C2.Field methods for measurement of fluvial sediment, by T.K. Edwards and G.D. Glysson: USGS—TWRI Book 3, Chapter C2. 1998. 80 pages.

3–C3.Computation of fluvial-sediment discharge, by George Porterfield: USGS—TWRI Book 3, Chapter C3. 1972. 66 pages.

Book 4. Hydrologic Analysis and Interpretation

Section A. Statistical Analysis

4–A1.Some statistical tools in hydrology, by H.C. Riggs: USGS—TWRI Book 4, Chapter A1. 1968. 39 pages.

4–A2.Frequency curves, by H.C. Riggs: USGS—TWRI Book 4, Chapter A2. 1968. 15 pages.

Section B. Surface Water

4–B1.Low-flow investigations, by H.C. Riggs: USGS—TWRI Book 4, Chapter B1. 1972. 18 pages.

4–B2.Storage analyses for water supply, by H.C. Riggs and C.H. Hardison: USGS—TWRI Book 4, Chapter B2. 1973. 20 pages.

4–B3.Regional analyses of streamflow characteristics, by H.C. Riggs: USGS—TWRI Book 4, Chapter B3. 1973. 15 pages.

Section D. Interrelated Phases of the Hydrologic Cycle

4–D1.Computation of rate and volume of stream depletion by wells, by C. T. Jenkins: USGS—TWRI Book 4, Chapter D1. 1970. 17 pages.

Book 5. Laboratory Analysis

Section A. Water Analysis

5–A1.Methods for determination of inorganic substances in water and fluvial sediments, by M.J. Fishman and L.C. Friedman, editors: USGS—TWRI Book 5, Chapter A1. 1989. 545 pages.

5–A2.Determination of minor elements in water by emission spectroscopy, by P.R. Barnett and E.C. Mallory, Jr.: USGS—TWRI Book 5, Chapter A2. 1971. 31 pages.

5–A3.Methods for the determination of organic substances in water and fluvial sediments, edited by R.L. Wershaw, M.J. Fishman, R.R. Grabbe, and L.E. Lowe: USGS—TWRI Book 5, Chapter A3. 1987. 80 pages.

5–A4.Methods for collection and analysis of aquatic biological and microbiological samples, by L.J. Britton and P.E. Greeson, editors: USGS—TWRI Book 5, Chapter A4. 1989. 363 pages.

5–A5.Methods for determination of radioactive substances in water and fluvial sediments, by L.L. Thatcher, V.J. Janzer, and K.W. Edwards: USGS—TWRI Book 5, Chapter A5. 1977. 95 pages.

5–A6.Quality assurance practices for the chemical and biological analyses of water and fluvial sediments, by L.C. Friedman and D.E. Erdmann: USGS—TWRI Book 5, Chapter A6. 1982. 181 pages.

Section C. Sediment Analysis

5–C1.Laboratory theory and methods for sediment analysis, by H. P. Guy: USGS—TWRI Book 5, Chapter C1. 1969. 58 pages.

Book 6. Modeling Techniques

Section A. Ground Water

6–A1.A modular three-dimensional finite-difference ground-water flow model, by M. G. McDonald and A. W. Harbaugh: USGS—TWRI Book 6, Chapter A1. 1988. 586 pages.

6–A2.Documentation of a computer program to simulate aquifer-system compaction using the modular finite-difference ground-water flow model, by S.A. Leake and D.E. Prudic: USGS—TWRI Book 6, Chapter A2. 1991. 68 pages.

6–A3.A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 1: Model Description and User's Manual, by L. J. Torak: USGS—TWRI Book 6, Chapter A3. 1993. 136 pages.

6–A4.A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 2: Derivation of finite-element equations and comparisons with analytical solutions, by R.L. Cooley: USGS—TWRI Book 6, Chapter A4. 1992. 108 pages.

6–A5.A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 3: Design philosophy and programming details, by L.J. Torak: USGS—TWRI Book 6, Chapter A5, 1993. 243 pages.

6–A6.A coupled surface-water and ground-water flow model (MODBRANCH) for simulation of stream-aquifer interaction by E.D. Swain and Eliezer J. Wexler: USGS—TWRI Book 6, Chapter A6, 1996. 125 pages.

Book 7. Automated Data Processing and Computations

Section C. Computer Programs

7–C1.Finite difference model for aquifer simulation in two dimensions with results of numerical experiments, by P.C. Trescott, G.F. Pinder, and S.P. Larson: USGS—TWRI Book 7, Chapter C1. 1976. 116 pages.

7–C2.Computer model of two-dimensional solute transport and dispersion in ground water, by L.F. Konikow and J.D. Bredehoeft: USGS—TWRI Book 7, Chapter C2. 1978. 90 pages.

7–C3.A model for simulation of flow in singular and interconnected channels, by R.W. Schaffranek, R.A. Baltzer, and D.E. Goldberg: USGS—TWRI Book 7, Chapter C3. 1981. 110 pages.

Book 8. Instrumentation

Section A. Instruments for Measurement of Water Level

8–A1.Methods of measuring water levels in deep wells, by M.S. Garber and F.C. Koopman: USGS—TWRI Book 8, Chapter A1. 1968. 23 pages.

8–A2.Installation and service manual for U.S. Geological Survey manometers, by J.D. Craig: USGS—TWRI Book 8, Chapter A2. 1983. 57 pages.

Section B. Instruments for Measurement of Discharge

8–B2.Calibration and maintenance of vertical-axis type current meters, by G.F. Smoot and C.E. Novak: USGS—TWRI Book 8, Chapter B2. 1968. 15 pages.

Book 9. Handbooks for Water-Resources Investigations

Section A. National Field Manual for the Collection of Water-Quality Data

9–A1.Preparations for water sampling, by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo: USGS—TWRI Book 9, Chapter A1. 1998. Variously paged.

9–A2.Selection of equipment for water sampling, by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo, editors: USGS—TWRI Book 9, Chapter A2. 1998. Variously paged.

9–A6.Field measurements, by F.D. Wilde and D.B. Radtke, editors: USGS—TWRI Book 9, Chapter A6. 1998. Variously paged.

9–A7.Biological indicators, by D.N. Myers and F.D. Wilde, editors: USGS—TWRI Book 9, Chapter A7. 1997. Variously paged.

9–A8.Bottom-material samples, by D.B. Radtke: USGS—TWRI Book 9, Chapter A8. 1998. Variously paged.

9–A9.Safety in field activities, by S.L. Lane and R.G. Fay: USGS—TWRI Book 9, Chapter A9. 1998. Variously paged.

ISBN 0-607-90623-5