Techniques of Water-Resources Investigations

Book 9
Handbooks for Water-Resources Investigations

National Field Manual for the Collection of Water-Quality Data

Chapter A4.
COLLECTION OF WATER SAMPLES

Edited by
F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo

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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

A1. Preparations for Water Sampling

A2. Selection of Equipment for Water Sampling

A3. Cleaning of Equipment for Water Sampling

A4. Collection of Water Samples

A5. Processing of Water Samples

A6. Field Measurements
- 6.0 General Information and Guidelines
- 6.1 Temperature
- 6.2 Dissolved Oxygen
- 6.3 Specific Electrical Conductance
- 6.4 pH
- 6.5 Reduction-Oxidation Potential (Electrode Method)
- 6.6 Alkalinity and Acid Neutralizing Capacity
- 6.7 Turbidity

A7. Biological Indicators
- 7.1 Fecal Indicator Bacteria
- 7.2 Five-Day Biochemical Oxygen Demand

A8. Bottom-Material Samples

A9. Safety in Field Activities

COLLECTION OF WATER SAMPLES A4.

National Field Manual for the Collection of Water-Quality Data

Chapter A4.

	Page
Abstract	7
Introduction	8
Purpose and scope	8
Requirements and recommendations	9
Field manual review and revision	10
Acknowledgments	11
A4. Collection of Water Samples	13
4.0 Techniques to prevent sample contamination F.D. Wilde and D.B. Radtke	15
4.0.1 Clean-sampling procedures	17
4.0.2 Field rinsing of equipment	19
4.0.2.A Surface-water bottle samplers and bag samplers	19
4.0.2.B Churn splitter	20
4.0.2.C Cone splitter	20
4.0.2.D Ground-water samplers	21

4.0.3 Avoiding exchange of sample with atmospheric gases 22

4.1 Surface-water sampling: collection methods at flowing-water and still-water sites 23
W.E. Webb, D.B. Radtke, and R.T. Iwatsubo

4.1.1 Flowing-water sites 24

4.1.1.A Isokinetic, depth-integrated sampling methods 25

Equal-width-increment (EWI) method 30

Equal-discharge-increment (EDI) method 39

Single vertical at centroid-of-flow (VCF) method 47

4.1.1.B Nonisokinetic dip, discrete, and pump sampling methods 49

4.1.2 Still-water sites 56

4.2 Ground-water sampling: preparations and purging methods at water-supply wells and monitoring wells 61
Jacob Gibs and F.D. Wilde

4.2.1 Water-supply wells 74

4.2.2 Monitoring wells 80

4.3 Quality-control samples 91
F.D. Wilde, T.L. Schertz, and D.B. Radtke

4.3.1 Blank samples 93

4.3.1.A Source-solution, equipment, trip, and other prefield blanks 94

4.3.1.B Ambient and field blanks 95

Ambient blanks 96

Field blanks 97

4.3.2 Replicate samples 99

4.3.2.A Concurrent replicate samples 99

4.3.2.B Sequential replicate samples 100

4.3.2.C Split replicate samples 100

4.3.3 Spike samples 101

4.3.4 Reference samples 102

4.3.5 Blind samples 103

Conversion factors, selected terms, and abbreviations CF–1

Selected references and internal documents.....REF–1

Publications on Techniques of Water-Resources Investigations TWRI–1

Appendix A4-A. Transit rate and volume guidelines for isokinetic sampling APP–A1

Tables showing:

1a. Isokinetic transit rates for a 1-liter bottle sampler with a 3/16-inch nozzle APP–A3

1b. Isokinetic transit rates for a 1-liter bottle sampler with a 1/4-inch nozzle APP–A5

1c. Isokinetic transit rates for a 1-liter bottle sampler with a 5/16-inch nozzle APP–A7

2a. Isokinetic transit rates for a 3-liter bottle sampler with a 1/4-inch nozzle APP–A9

2b. Isokinetic transit rates for a 3-liter bottle sampler with a 5/16-inch nozzle APP–A11

3a. Minimum volumes for isokinetic sampling with a bag sampler APP–A13

3b. Isokinetic transit rates for a 3-liter bag sampler with a 1/4-inch nozzle APP–A15

3c. Isokinetic transit rates for a 3-liter bag sampler with a 5/16-inch nozzle APP–A17

Appendix A4-B. Quality-control samples collected by field personnel for water-quality studies APP–B1

Appendix A4-C. Examples from the National Water-Quality Assessment Program related to protocols for collecting blank samples at ground-water sampling sites APP–C1

1. Example of procedure to estimate and collect field volumes of blank solutions..... APP–C2

2. Example of procedure to collect blank samples with a submersible pump APP–C3

Illustrations

4-1. Relation between intake velocity and sediment concentration for isokinetic and nonisokinetic collection of water samples that contain particulates greater than 0.062 millimeters 27

4-2. Equal-width-increment method for collection of water samples..... 31

4-3. Equal-discharge-increment method for collection of water samples 40

4-4. Discharge-measurement field notes used to determine the equal-discharge-increment centroid locations based on cumulative discharge and far-midpoint stationing..... 43

4-5. Example of a manifold used for well purging and sample collection 64

4-6. Estimation of purge volume and purge time 71

4-7. Example of field form for a record of well purging 72

4-8. Example of procedure for collecting field blanks and associated blank samples..... 98

Tables

4-1. Good field practices for collection of water-quality samples 16

4-2. Clean Hands/Dirty Hands techniques for water-quality sampling 18

4-3. Uses and advantages of equal-width-increment and equal-discharge-increment sampling methods 29

4-4. Considerations for maintaining the integrity of ground-water samples..... 66

4-5. Advantages and disadvantages of collecting water samples from supply wells with permanently installed pumps..... 74

Chapter A4. COLLECTION OF WATER SAMPLES

Edited 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 that are used to assess the quality of the Nation's surface-water and ground-water resources. This chapter provides information and addresses appropriate methods for the collection of surface-water, ground-water, and associated quality-control samples. Among the topics covered are procedures to prevent sample contamination; instructions for collecting isokinetic, depth-integrated samples from streams; and guidelines and criteria for purging wells in preparation for collecting samples from ground water.

Each chapter of the *National Field Manual* is 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 the 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 those data on surface-water and ground-water resources. Chapter A4 provides information about the collection of water samples for investigations and assessments of environmental water quality. **Formal training and field apprenticeship are necessary in order to implement correctly the procedures described in this chapter.**

The *National Field Manual* is Section A of Book 9 of the USGS publication series "Techniques of Water-Resources Investigations" (TWRI) and consists of individually published chapters designed to be used in conjunction with each other. Chapter numbers are preceded by an "A" to indicate that the report is part of the *National Field Manual*. Other chapters of the *National Field Manual* are referred to in this report by the abbreviation "NFM" and the specific chapter number (or chapter and section number). For example, NFM 6 refers to Chapter A6 on "Field Measurements" and NFM 6.4 refers to the section on field measurement of pH.

The procedures described in this chapter represent protocols that are generally applicable to USGS studies involving the collection of water-quality data. Modification of required and recommended procedures to fulfill study objectives or to enhance data quality must be documented and published with the data and data interpretation.

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.

The purpose of this chapter of the *National Field Manual* is to provide field personnel and other interested parties with a description of the requirements, recommendations, and guidelines routinely used in USGS studies involving the collection of water-quality samples. The information provided covers topics fundamental to the collection of water samples that are representative of the ambient environment. The information provided does not attempt to encompass the entire spectrum of data-collection objectives, site characteristics, environmental conditions, and technological advances related to water-quality studies. Also beyond the scope of this chapter is discussion of procedures to collect samples for analysis of suspended or biological materials.

REQUIREMENTS AND RECOMMENDATIONS

As used in the *National Field Manual* , the terms **required** and **recommended** have 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 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 referenced in this chapter. 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 based on referenced research and good field judgment, and be quality assured and documented.

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

Recommended (recommend, recommended, recommendation) pertains to USGS protocols and indicates that, on the basis of research and (or) consensus, the USGS Office of Water Quality recognizes one or several acceptable alternatives for selecting equipment or procedures. Specific data-quality requirements, study objectives, or other constraints might affect the choice of recommended equipment or procedures. Selection from among the alternatives must be based on referenced research and good field judgment, and reasons for the selection should 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 correct any errors, incorporate technical advances, and address additional topics. Comments or corrections can be mailed to NFM-QW, USGS, 412 National Center, Reston, VA 20192 (or direct electronic mail to nfm-owq@usgs.gov). Information regarding the status and any errata of this or other chapters can be found near the beginning of the electronic version of each chapter, located in the Publications section of the following Web site: http://water.usgs.gov/lookup/get?owq. 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," at http://water.usgs.gov/lookup/get?newpubs.

ACKNOWLEDGMENTS

The information included in this chapter of 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 included USGS handbooks, manuals, and technical memorandums. The editors and authors wish to acknowledge the following individuals in the USGS who developed the field and training manuals that provided the foundation for information on the collection and processing of water samples: M.E. Dorsey, T.K. Edwards, W.B. Garrett, W.J. Gibbons, R.T. Kirkland, L.R. Kister, J.R. Knapton, C.E. Lamb, R.F. Middelburg, J. Rawson, L.R. Shelton, M.A. Sylvester, and F.C. Wells.

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COLLECTION OF WATER SAMPLES A4.

This chapter of the *National Field Manual* describes standard USGS methods (sampling strategies, techniques, requirements, and recommendations) for routine collection of representative water samples. A representative sample is one that typifies the ambient targeted characteristics of the media of interest at the time of collection. Obtaining representative samples is of primary importance for an accurate description of the environment. In order to collect a representative sample that will yield the information required, (1) study objectives, including data-quality requirements,[2] must be understood in the context of the water system to be sampled and (2) artifacts of the sampling process must be minimized.[3] Field personnel must be alert to conditions that could compromise the quality of a sample.

- **Think contamination!** To ensure the integrity of the sample, be aware of possible sources of contamination. Contamination introduced during each phase of sample collection (and processing) is additive and usually is substantially greater than contamination introduced elsewhere in the sample-handling and -analysis process. **Collect sufficient quality-control samples.**
- **Collect a representative sample.** Use appropriate procedures and quality-assurance measures that ensure sample representativeness and integrity and that meet study criteria.

[2]As used in this report, data-quality requirements refer to that subset of data-quality objectives pertaining to the analytical detection level for concentrations of target analytes and the variability allowable to fulfill the scientific objectives of the study.

[3]The degree to which a sample can be considered representative of a water body depends on many interrelated factors including, for example, temporal and spatial homogeneity of the water body, sample size, and the method and manner of sample collection.

Before field work begins, review the preparations for water sampling described in NFM 1 and the safety requirements described in NFM 9. Sampling plans should be prepared and reviewed in advance. Some programs require chain-of-custody documentation and (or) a prescribed format for sampling and safety plans (SAPs).

- **Never compromise the safety of field personnel.**
- **Become thoroughly familiar with sample processing requirements (NFM 5) before proceeding to collect water samples**.
- **Keep clear and precise field records.** Implement the methods described in this chapter conscientiously and consistently, as appropriate to study objectives and site conditions. **Any departure from standard methods needs to be documented, quality assured, and reported with the data and interpretation of the data.**

Sample collection forms a continuum with sample processing, and information in this chapter (such as collecting quality-control samples) overlaps to some extent with the information in NFM 5 for processing of water samples.

TECHNIQUES TO PREVENT SAMPLE CONTAMINATION 4.0

By **F.D. Wilde and D.B. Radtke**

Contamination of water samples can be prevented by planning the order in which sites will be sampled and by recognizing potential sources of contamination. NFM 1 provides information on reconnaissance of field sites. Sites should be sampled in the order of least to greatest potential for equipment fouling or contamination. The cleanest sites are often those that are in pristine environments, in areas where concentrations of dissolved solids are low, or upstream or upgradient from known or suspected sources of contamination.

The most common causes of sample contamination during sample collection include poor sample-handling techniques, atmospheric input, inadequately cleaned equipment, and use of equipment constructed of materials inappropriate for the analytes targeted for study. Contamination of samples from these sources can be prevented or minimized by adhering to good field practices (table 4-1). Use of Clean Hands/Dirty Hands sampling techniques is described in section 4.0.1, along with other clean-sampling procedures. Field rinsing of equipment to be used to collect and process samples is described in section 4.0.2. The considerations and planning required for collecting ground-water or other samples that contain gases are described in section 4.0.3. Collection of equipment blanks and field blanks is necessary to help identify potential sources of sample contamination (section 4.3). The same equipment that is used to collect (and/or process) environmental samples is to be used to collect (and/or process) blank samples.

Sample at sites with the least contamination or lowest chemical concentrations first.

Table 4-1. Good field practices for collection of water-quality samples

[Modified from "Rules for Trace-Metal Sampling" by Howard Taylor, U.S. Geological Survey, written communication, 1992; NFM, *National Field Manual for the Collection of Water-Quality Data*]

- Be aware of and record potential sources of contamination at each field site.
- Wear appropriate disposable, powderless gloves:
  - Change gloves before each new step during sample collection (and processing).
  - Avoid hand contact with contaminating surfaces (such as equipment, coins, food).
- Use equipment constructed of materials that are relatively inert with respect to the analytes to be collected (NFM 2).
- Use only equipment that has been cleaned according to prescribed procedures (NFM 3).
- Field rinse equipment, but only as directed. Some equipment for some analytes should not be field rinsed.
- Use correct sample-handling procedures:
  - Minimize the number of sample-handling steps.
  - Use Clean Hands/Dirty Hands techniques (table 4-2) as required for parts-per-billion trace-element sampling. Adapt Clean Hands/Dirty Hands techniques for other sample types, as appropriate. Obtain training for and practice field techniques under supervision before collecting water samples.
- Collect (and process) samples in enclosed chambers so as to minimize contamination from atmospheric sources.
- Collect a sufficient number of appropriate types of quality-control samples.
- Follow a prescribed order for collecting samples.

CLEAN-SAMPLING PROCEDURES 4.0.1

Clean-sampling procedures (sometimes called the parts-per-billion or ppb protocol) involve (1) using equipment that is constructed of noncontaminating materials (NFM 2) and that has been cleaned rigorously before field work and between field sites (NFM 3); (2) handling equipment in a manner that minimizes the chance of altering ambient sample composition; (3) handling samples in a manner that prevents contamination; and (4) routinely collecting quality-control (QC) samples. Clean Hands/Dirty Hands (*CH/DH*) techniques separate field duties and dedicate one individual (designated as Clean Hands) to tasks related to direct contact with the sample. *CH/DH* techniques are summarized on table 4-2. Implementation of this protocol requires hands-on training and field-team coordination.[4] **The field team must be trained in and practice these procedures before using them to collect samples.**

Clean-sampling procedures, including *CH/DH* techniques, were developed for collecting (and processing) samples vulnerable to contamination.

- **Requirement:** Clean-sampling procedures (such as *CH/DH* techniques) are required when collecting samples for analysis of metals and other inorganic trace elements (hereafter referred to collectively as trace elements), as follows:
  - For trace elements with ambient concentrations at or near 1 µg/L.
  - For iron, aluminum, or manganese with ambient concentrations to about 200 µg/L.
- **Recommendation:** Clean-sampling procedures are recommended when collecting samples for analysis of most trace elements with concentrations to about 100 µg/L.

[4]A detailed description of Clean Hands/Dirty Hands techniques can be found in Horowitz and others (1994). Clean Hands/Dirty Hands techniques also are included in procedures for equipment cleaning (refer to NFM 3) and sample processing (refer to NFM 5).

▶ **Recommendation:** Clean-sampling techniques are recommended when collecting samples for analysis of trace-organic compounds and major inorganic elements, particularly when the target analyte could be subject to contamination from field or laboratory procedures at a level that could exceed data-quality requirements.

Table 4-2. Clean Hands/Dirty Hands techniques for water-quality sampling

- Clean Hands/Dirty Hands techniques require two or more people working together.
- At the field site, one person is designated as Clean Hands (*CH*) and a second person as Dirty Hands (*DH*). Although specific tasks are assigned at the start to *CH* or *DH*, some tasks overlap and can be handled by either, as long as the prescribed care is taken to prevent contaminating the sample.
- Both *CH* and *DH* wear appropriate disposable, powderless gloves during the entire sampling operation and change gloves frequently, usually with each change in task. (Wearing multiple layers of gloves allows rapid glove changes.) **Gloves must be appropriate to withstand any acid, solvent, or other chemical substance that will be used or contacted.**
- *CH* takes care of all operations involving equipment that contacts the sample; for example, *CH*
  - Handles the surface-water sampler bottle.
  - Handles the discharge end of the surface-water or ground-water sample tubing.
  - Transfers sample to churn or cone splitter.
  - Prepares a clean work space (inside vehicle).
  - Sets up processing and preservation chambers.
  - Places equipment inside chambers (for example, sample bottles, filtration and preservation equipment).
  - Works exclusively inside chambers during collection/processing and preservation.
  - Changes chamber covers, as needed.
  - Sets up field-cleaning equipment and cleans equipment.
- *DH* takes care of all operations involving contact with potential sources of contamination; for example, *DH*
  - Works exclusively exterior to processing and preservation chambers.
  - Prepares and operates sampling equipment, including pumps and discrete samplers, peristaltic pump switch, pump controller, manifold system.
  - Operates cranes, tripods, drill rigs, vehicles, or other support equipment.
  - Handles the compressor or other power supply for samplers.
  - Handles tools such as hammers, wrenches, keys, locks, and sample-flow manifolds.
  - Handles single or multiparameter instruments for field measurements.
  - Handles the churn carrier, including outer protective bags.
  - Handles stream-gaging or water-level equipment.
  - Sets up and calibrates field-measurement instruments.
  - Measures and records water levels and field measurements.

FIELD RINSING OF EQUIPMENT 4.0.2

Most equipment used for sample collection and processing is field rinsed with the water to be sampled just before the water samples are collected (some exceptions are described below). The purposes of field rinsing are to condition, or equilibrate, the equipment to the sample environment and to help ensure that all cleaning-solution residues have been removed before sampling begins.[5] The Clean Hands team member is responsible for field rinsing the equipment whenever *CH/DH* techniques are used. Field-rinsing procedures are summarized below for sampling devices and for sample-compositing and sample-splitting equipment. Field-rinsing procedures are discussed in detail in Horowitz and others (1994) and Koterba and others (1995).

Field rinsing of equipment does not substitute for equipment cleaning.

Surface-Water Bottle Samplers and Bag Samplers 4.0.2.A

Sampling devices used to collect water samples from surface water are described in NFM 2. A bottle- or bag-type sampler is used for most routine sampling in streams. If a pump sampler will be used, refer to section 4.1.2, step 4B.

To field rinse a surface-water sampler:

1. Put on appropriate disposable, powderless gloves (gloves).
2. Partially fill and rinse the sampler with the water to be sampled (rinse water). Avoid getting sand in the rinse water.
3. Shake or swirl and then drain the rinse water from the sampler through the nozzle. (For bag samplers, the bag must be removed from the sampler to properly discard final rinse water.)

[5]Cleaning procedures and subsequent collection of the equipment blank are described in NFM 3.

4.0.2.B Churn Splitter

Surface-water samples commonly are composited in a churn splitter that has a funnel attached to the lid (NFM 2 and NFM 5.1.1.A).

To field rinse the churn splitter:

1. Put on gloves.
2. Pour 2 to 4 L of rinse water from the sampler into the churn splitter (churn) through the top funnel.
3. Remove the churn from the churn carrier, leaving the outer plastic bag inside the carrier. Move the churn disk up and down several times to ensure that the inside of the churn is thoroughly wetted, then swirl the rinse water vigorously in the churn.
4. Pierce a hole through the inner plastic bag to expose the churn spigot and drain the rinse water through the spigot. **If sand is present**, swirl water vigorously in the churn, open the plastic bag, and partially lift the churn cover to pour the rinse water out of the top of the churn. (Draining the rinse water through the spigot will not adequately remove sand.)
5. After the rinse water has been drained from the churn, rotate the churn in the plastic bag so that the spigot is no longer exposed. Place the inner plastic bag holding the churn into an outer plastic bag and place into the churn carrier.

4.0.2.C Cone Splitter

The cone splitter is required for specific site conditions (NFM 5.1.1.B) and is the sample splitter of choice for some water-quality data-collection programs.

To field rinse the cone splitter:

1. Put on gloves.
2. Uncover the splitter reservoir and pour or pump 2 to 4 L of rinse water into the cone-splitter reservoir.
3. Lightly tap the splitter to dislodge adhering water drops. Discard rinse water.
4. Cover the splitter.

Ground-Water Samplers 4.0.2.D

Samples of ground water from monitoring wells generally are collected using either a submersible pump, a peristaltic or valveless metering pump, or a point sampler such as a bailer, thief sampler, or syringe (NFM 2).

To field rinse a ground-water sampler:

1. Put on gloves.
2. Lower the sampler carefully through the water column in the well to the selected depth interval for sampling. **When lowering the sampler, take care to minimize disturbance to the water column and to sediments at the bottom of the well.**
   - If using a pump sampler, run water continuously through the pump and sample tubing to the waste container to achieve the equivalent volume of three equipment rinses. Field rinsing is accomplished with well purging, provided that the well will be purged with the same equipment to be used for sample withdrawal.
   - If using a bailer or other point sampler, follow the same procedure as for the surface-water bottle sampler (section 4.0.2.A).
3. Discard or contain the purge water used for field rinsing, as appropriate. Comply with waste-disposal regulations if water contaminated with toxic levels of chemicals is withdrawn from the well.

4.0.3 AVOIDING EXCHANGE OF SAMPLE WITH ATMOSPHERIC GASES

Collection of environmental samples from water bodies for which concentrations of dissolved gases differ significantly from atmospheric concentrations might require special field equipment or procedures. Water bodies isolated from the atmosphere or with dissolved-oxygen concentrations substantially less than that of air can be found in surface-water systems but are more common in ground-water systems. For such sites, exposure of the sample to the atmosphere can increase dissolved-oxygen concentrations, causing reduced metal ions to oxidize and precipitate as a hydroxide (for example, oxidation of iron species from ferrous (Fe^{+2}) to ferric (Fe^{+3}) iron). Precipitation of the iron or other metal hydroxide before or during filtration results in lower concentrations of iron and co-precipitating metals in the analyzed sample than are ambient in the ground water. Examples of nonmetal analytes for which atmospheric exposure can compromise sample integrity include volatile organic compounds (VOCs), pH, alkalinity, chlorofluorocarbons (CFCs), and some bacteria. Equipment and procedures should be selected that minimize contact with the atmosphere or minimize the effect of pressure changes from the source of the sample to the point of field measurement or sample processing. **In general, to maintain sample integrity for environments of limited atmospheric circulation:**

- Use pump and tubing conveyances that minimize entrainment of atmospheric gases or use equipment designed to collect and contain sample in situ.
- Use inline flowthrough sample-collection and sample-processing systems (NFM 6.2.2).
- Transport samples that need to be processed at the surface inline to a chamber filled with an inert gas such as nitrogen. This prevents oxidation but does not prevent degassing.

SURFACE-WATER SAMPLING: COLLECTION METHODS AT FLOWING-WATER AND STILL-WATER SITES 4.1

By **W.E. Webb, D.B. Radtke, and R.T. Iwatsubo**

The methods used to collect surface-water samples depend not only on flow characteristics of the surface-water body but also on the following considerations: safety of field personnel (NFM 9); nature of streamflow; field-measurement profiles (NFM 6); temporal and spatial heterogeneity; physical setting; ecological characteristics; weather conditions; fluvial-sediment transport; target analytes; point and nonpoint sources of contamination; and study objectives, including data-quality requirements. Each sampling site needs to be examined and sampled in a manner that minimizes bias caused by the collection process and that best represents the environmental conditions at the time of sampling.

The field team should be thoroughly familiar with procedures and requirements described in the *National Field Manual* and Office of Water Quality Technical Memorandum 99.02[6] before beginning field work. Standard references that provide descriptions of surface-water sampling techniques include: Federal Inter-Agency Sedimentation Project (1986), Ward and Harr (1990), and Edwards and Glysson (1998). Study requirements for quality control (QC) must be checked and previous QC data examined before field work begins.

- The field team should review requirements and procedures for collection of equipment blanks, field blanks, concurrent samples, and other relevant QC samples before beginning field work (section 4.3).
- The field team should be adequately staffed and equipped. For example, additional personnel and equipment are required for collection of concurrently collected samples (concurrent replicate samples, section 4.3).

[6]The technical memorandums referenced in this manual are available on the World Wide Web; see "Selected References and Internal Documents" for memorandum titles, dates, and the Web site address.

4.1.1 FLOWING-WATER SITES

Flowing streamwater is collected using either isokinetic, depth-integrating or nonisokinetic sampling methods. Isokinetic, depth-integrating methods are designed to produce a discharge-weighted (velocity-weighted) sample; that is, each unit of stream discharge is equally represented in the sample (Office of Water Quality Technical Memorandum 99.02). The analyte concentrations determined in a discharge-weighted sample are multiplied by the stream discharge to obtain the discharge of the analyte.

Collection of an isokinetic, depth-integrated, discharge-weighted sample is standard procedure; however, site characteristics, sampling-equipment limitations, or study objectives constrain how a sample is collected and could necessitate use of other methods. If the QC plan calls for collection of concurrent samples, then the relevant procedures must be reviewed and the appropriate equipment prepared (section 4.3).

Nonisokinetic sampling methods, such as those involving use of an automated point sampler, generally do not result in a discharge-weighted sample unless the stream is completely mixed laterally and vertically. Thus, the analytical results cannot be used to directly compute analyte discharges.

Document the sampling method used on the appropriate field form for each sample.

Isokinetic, Depth-Integrated Sampling Methods 4.1.1.A

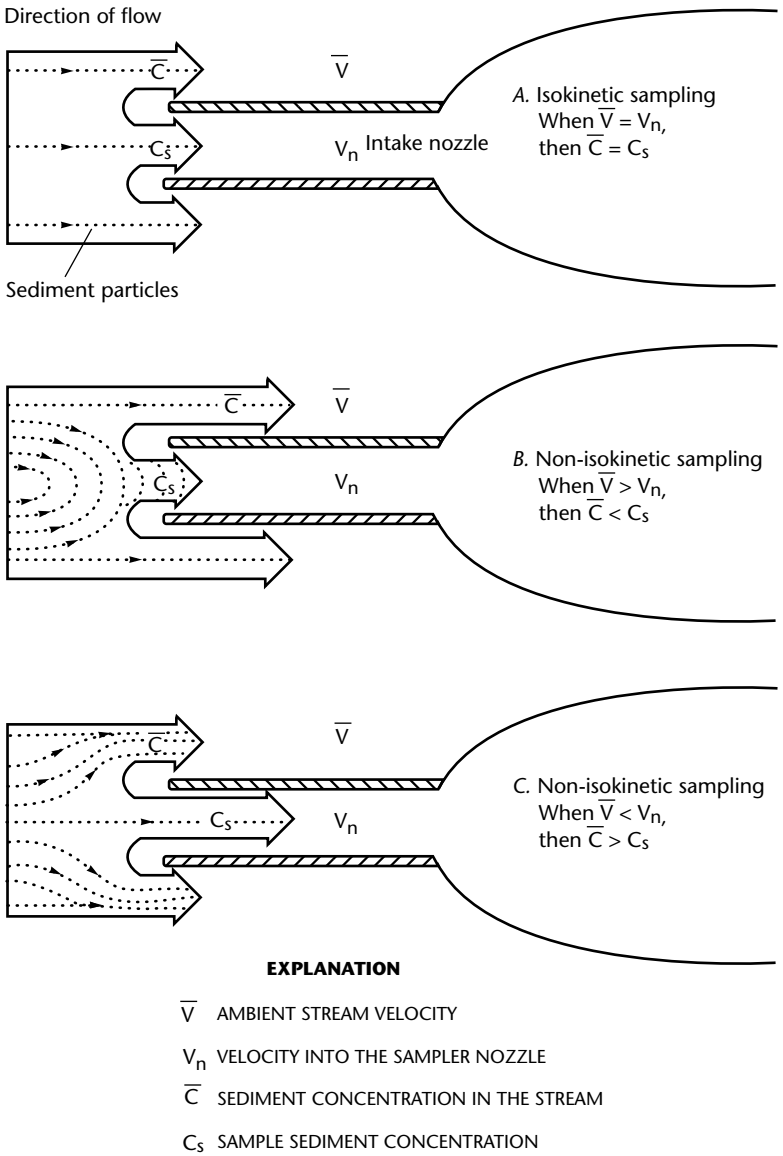
Collection of isokinetic, depth-integrated samples involves using either an equal-width-increment (EWI) or equal-discharge-increment (EDI) sampling method. The EWI or EDI methods usually result in a composite sample that represents the discharge-weighted concentrations of the stream cross section being sampled. The EWI and EDI methods are used to divide a selected cross section of a stream into increments having a specified width. The term **vertical** refers to that location within the increment at which the sampler is lowered and raised through the water column. EWI verticals are located at the midpoint of each width increment. EDI verticals are located at the centroid, a point within each increment at which stream discharge is equal on either side of the vertical.

Isokinetic samplers usually are used to obtain a discharge-weighted sample along the stream cross section. When using an isokinetic sampler there should be no change in velocity (speed and direction) as the sample enters the intake (fig. 4-1). If properly implemented, EDI and EWI methods should yield identical results. The uses and advantages of each method are summarized below and in table 4-3.

- Collect isokinetic, depth-integrated samples by using a standard depth- and width-integrating method if analysis of a representative sample from a cross section of flowing water is required for discharge computations. Appendix A4-A and Edwards and Glysson (1998, figures 39-43), provide detailed information about isokinetic, depth-integrating transit rates for collecting samples.

- For isokinetic sampling, the mean velocity of the vertical that is sampled must exceed the minimum-velocity requirement of an isokinetic sampler—the minimum velocity requirement is either 1.5 ft/s for a bottle sampler or 3 ft/s for a bag sampler (Appendix A4-A; NFM 2).
  - The transit rate (the rate at which the sampler is lowered or raised) used to collect an isokinetic, depth-integrated sample is mainly a function of the nozzle diameter of the sampler, volume of the sampler container, stream velocity, and sampling depth (Appendix A4-A; NFM 2). Note that water temperature can affect isokinetic sampling. For example, bag samplers do not work isokinetically in water temperatures that are less than about 7 °C.
  - An error in concentrations of suspended particulates coarser than 62 mm can be significant when the velocity of the sample entering the nozzle and the stream velocity differ significantly. The velocity of the sample entering the nozzle also can be affected by the transit rate: too fast a transit rate will cause a sampler to undersample sand-sized particulates (Edwards and Glysson, 1998).
  - The transit rate must be kept constant during sampler descent through a vertical and also during sampler ascent through a vertical. Although not necessary, usually the same transit rate is used for raising the sampler as was used for lowering the sampler through a given vertical.

C RULE OF THUMB: For isokinetic, depth-integrating sampling, do not exceed the designated maximum transit rate.



EXPLANATION

$\overline{V}$ AMBIENT STREAM VELOCITY

V_n VELOCITY INTO THE SAMPLER NOZZLE

$\overline{C}$ SEDIMENT CONCENTRATION IN THE STREAM

C_s SAMPLE SEDIMENT CONCENTRATION

Figure 4-1. Relation between intake velocity and sediment concentration for isokinetic and nonisokinetic collection of water samples that contain particulates greater than 0.062 millimeters (modified from Edwards and Glysson, 1998, p. 13).

The number of increments needed in order to get a discharge-weighted sample at a site is related primarily to data objectives (for example, the accuracy needed) and how well-mixed or heterogeneous the stream is with respect to the physical, chemical, and biological characteristics of the cross section. The recommended number of increments for EWI and EDI methods are discussed in the sections to follow. Edwards and Glysson (1998) describe a statistical approach for selecting the number of increments to be used, based on sampling error and suspended-sediment characteristics.

Selecting the number of increments

- Examine the variation in field-measurement values (such as specific electrical conductance, pH, temperature, and dissolved oxygen) along the cross section (NFM 6).
- Consider the distribution of streamflow (discharge), suspended-materials concentration and particle-size distribution, and concentrations of other targeted analytes along the cross section. Consider whether the distribution or analyte concentrations will change during sample collection.
- Consider the type of sampler that will be used and the volume of sample that will have to be collected for the analysis of the target analytes.
- Avoid side-channel eddies. EDI and EWI methods cannot be used at locations with upstream eddy flow.

Table 4-3. Uses and advantages of equal-width-increment (EWI) and equal-discharge-increment (EDI) sampling methods

EWI method	Advantages of the EWI method
EWI is used when information required to determine locations of sampling verticals for the EDI method is not available, and (or) the stream cross section has relatively uniform depth and velocity. **Use EWI whenever:** • The location of EDI sampling verticals changes at the same discharge from one sampling time to another. This situation occurs frequently in streams with sand channels.	• EWI method is easily learned and implemented for sampling small streams. • Generally, less time is required onsite if the EWI method can be used and information required to determine locations of sampling verticals for the EDI method is not available.
EDI method	**Advantages of the EDI method**
EDI is used when information required to determine locations of sampling verticals for the EDI method is available. **Use EDI whenever:** • Small, nonhomogeneous increments need to be sampled separately from the rest of the cross section. The samples from those verticals can be analyzed separately or appropriately composited with the rest of the cross-sectional sample. (Have the sampling scheme approved.) or • Flow velocities are less than the isokinetic transit-rate range requirement. A discharge-weighted sample can be obtained, but the sample will not always be isokinetic. or • The EWI sampling method cannot be used. For example, isokinetic samples cannot be collected because stream velocities and depths vary so much that the isokinetic requirements of the sampler are not met at several sampling verticals. or • Stage is changing rapidly. (EDI requires less sampling time than EWI, provided the locations of the sampling verticals can be determined quickly.)	• Fewer increments are necessary, resulting in a shortened sampling time (provided the locations of sampling verticals can be determined quickly and constituents are adequately mixed in the increment). • Sampling during rapidly changing stages is facilitated by the shorter sampling time. • Subsamples making up a sample set may be analyzed separately or may be proportionally composited with the rest of the cross-sectional sample. • The cross-sectional variation in constituent discharge can be determined if subsample bottles are analyzed individually. • A greater range in velocity and depths can be sampled isokinetically at a cross section. • The total composite volume of the sample is known and can be adjusted before sampling begins.

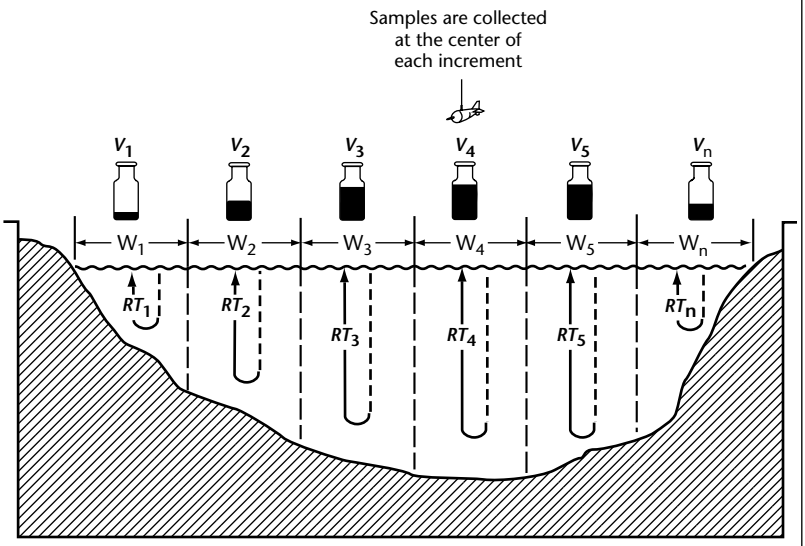
Equal-width-increment (EWI) method

For the EWI sampling method, the stream cross section is divided into a number of equal-width increments (fig. 4-2). Samples are collected by lowering and raising a sampler through the water column at the center of each increment. (This sampling location is referred to as the vertical.) The combination of the same constant transit rate used to sample at each vertical and the isokinetic property of the sampler results in a discharge-weighted sample that is proportional to total streamflow.

- **Isokinetic sampling is required for the EWI method.** Use isokinetic, depth-integrating sampling equipment (NFM 2).
  - **Use the same size sampler container (bottle or bag) and nozzle** at each of the sampling verticals (fig. 4-2).
  - **Collect samples using the same transit rate** at each vertical during descent and ascent of the sampler. The transit rate must be constant and within the operational range of the sampler (Appendix A4-A).
- Composite the subsamples from all verticals in a churn splitter or process subsamples through the cone splitter (NFM 5).

Do not use EWI when stream velocities are less than the minimum velocity required for the isokinetic sampler selected:

- **1.5 ft/s for the bottle sampler**
- **3 ft/s for the bag sampler**



EXPLANATION

RT TRANSIT RATE (transit rate at each sampling vertical is equal)

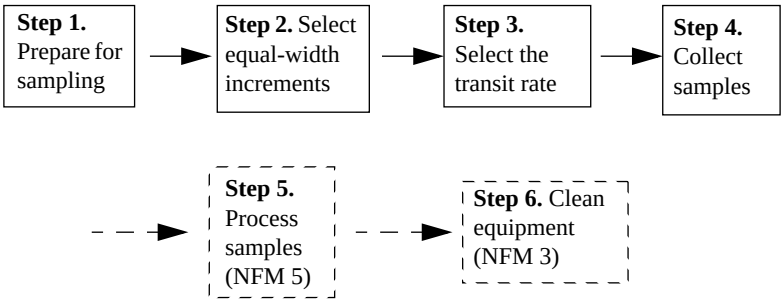
W WIDTH (width of each increment is equal)

V VOLUME COLLECTED AT EACH VERTICAL IS PROPORTIONAL TO THE DISCHARGE OF EACH INCREMENT

SAMPLING VERTICAL OF EACH EQUAL-WIDTH INCREMENT (SAMPLES COLLECTED)—The vertical transit rate relative to sample volume that is proportional to the stream discharge of each increment

Figure 4-2. Equal-width-increment method for collection of water samples (modified from Edwards and Glysson, 1998).

Guidelines for the EWI sampling method



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Step 1. Prepare for sampling[7]

a. Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle in a location and direction so as to prevent sample contamination from vehicle emissions.

b. Assemble sampling equipment and set up a clean work space.

- **Organic compounds**. Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics other than fluorocarbon polymers.**
- **Inorganic constituents**. Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
- **Microbiological analyses**. Collect samples for microbiological analyses using equipment and techniques described in NFM 7.

[7]Preparations for water sampling are described in NFM 1, 2, and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling and NFM 9 for field safety.

Step 2. Select the number and width of equal-width increments.

a. Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, and depth distribution, and apparent distribution of sediment and aquatic biota along the cross section. Note and document the location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other features along the cross section.

b. Determine stream width from a tagline or from distance markings on a bridge railing or cableway.

c. At sites with little sampling history, measure and record the cross-sectional variation of field measurements (such as specific electrical conductance, pH, temperature, and dissolved oxygen). Review the magnitude of the variations along the cross section.

d. Determine the width of the increment. To obtain the number of increments, divide the stream width by the increment width. **The number of increments must be a whole number**. Increment width is based on study objectives, variation in field measurements and flow, and stream-channel characteristics along the cross section.

   - Collect the subsample at the center of each equal-width increment (the vertical).
   - If the subsample does not represent the mean value for that increment, decrease the increment width until the mean value for the increment is represented. This will increase the number of increments sampled.

e. Locate the first sampling vertical at a distance of one-half of the selected increment width from the edge of the water. Locate all the other verticals at the center of each remaining equal-width increment along the cross section.

   Example:

   - If a stream 56 ft wide has been divided into 14 increments of 4 ft each, the first sampling vertical would be 2 ft from the water's edge and subsequent verticals would be at 6, 10, 14 ft from the water's edge, and so forth.
   - Even if streamflow is divided, as in a braided channel, equal-width increments must be identical from channel to channel, and the same constant transit rate must be used at each vertical.

f. Make slight adjustments to sampling locations, if necessary, to avoid sampling where the flow is affected by a pier or other obstruction.

TECHNICAL NOTE: Sampling near or downstream from large in-stream obstructions such as bridges and piers could result in artificially elevated concentrations of suspended sediments if the sampler is immersed in an eddy that is caused by the obstruction. If it is necessary to include an eddy in the cross section to be sampled, consider treating the eddy as a solid obstruction: subtract the eddy width from that of the total cross section, and determine the width of the increments based on the remaining stream width.

C RULE OF THUMB

When selecting the number of equal-width increments:

- Cross-sectional width ≥ 5 ft—use a minimum of 10 equal-width increments.
- Cross-sectional width <5 ft—use as many increments as practical, but equally spaced a minimum of 3 in. apart.

Equipment limitations also constrain the number of increments selected; for example:

- When using a D-95 at maximum depth with a 14-L churn splitter, EWI samples can be collected at approximately 14 verticals. If an 8-L churn splitter is used, samples can be collected at approximately 10 verticals.
- When using a D-77 and a 14-L churn splitter, the maximum average depth must not exceed 5 ft when samples are collected at 10 verticals.

Step 3. Select the transit rate.

a. Refer to Appendix A4-A for guidelines for determining the transit rates for collecting isokinetic, depth-integrated samples. Unless the mean velocity is actually determined, use the trial-and-error method to determine the minimum transit rate.

b. Locate the equal-width increment containing the largest discharge (largest product of depth times velocity) by sounding for depth and either measuring or estimating velocity. At the vertical for this increment, use of the minimum transit rate results in the maximum allowable filling of the sampler bottle or bag during one vertical traverse.

c. Determine the minimum transit rate at this vertical for the type of sampler (bottle or bag), size of sampler nozzle, and the desired sample volume.

- Approximate the mean velocity of the vertical in feet per second by timing a floating marker (such as a peanut) as it travels a known distance. (A known length of flagging tape tied to the cable where the sampler is attached often is used to measure the distance.) Divide the distance (in feet) by the time (in seconds) and multiply by 0.86.
- Make sure that the transit rate does not exceed the maximum allowable transit rate to be used at any of the remaining verticals along the cross section. This can be determined by sampling the slowest increment. **If the minimum volume of sample (relative to depth of the vertical) is not collected at this vertical, then the EWI method cannot be used at this cross section to collect a discharge-weighted sample (Appendix A4-A).**

Guidelines for selecting the transit rate for EWI sampling
• **The descending and ascending transit rate must be constant in each direction and must be the same for each vertical along the cross section.**
• **Do not exceed the maximum allowable transit rate if using EWI.** If the transit rate must exceed the maximum allowable rate, use EDI instead of EWI.
• The transit rate selected must be sufficiently rapid to keep from overfilling the sampler. The sampler is overfilled when the water surface in the sampler container is above the bottom edge of the nozzle when the sampler is held in the sampling position.
• The same size sampler nozzle and container must be used at all verticals along the cross section.
• If the total volume collected will exceed the recommended volume for the churn splitter, then a cone splitter must be used.

Step 4. Collect samples.

The sample-collection procedure is the same whether you are wading or using the reel-and-cable suspension method. **Use *CH/DH* techniques, as required (section 4.0.1). Always follow safety procedures (NFM 9)**.

a. Move to the first vertical (midpoint of first EWI near edge of water) and field rinse equipment (section 4.0.2).

b. Record start time and gage height.

c. Lower field-rinsed sampler at the predetermined constant transit rate until slight contact is made with the streambed. **Do not pause** upon contacting the streambed. Raise the sampler immediately at the same constant transit rate until sampler completes the vertical traverse.

- Take care not to disturb the streambed by bumping the sampler on it; bed material may enter the nozzle, resulting in erroneous data.
- Do not overfill the sampler container. Overfilling results in a sample that is not isokinetic and that could be enriched with heavy particulates because of secondary circulation of water through the sampler (from nozzle through air exhaust). This enrichment will result in an artificially increased sediment concentration and will bias particle-size distribution toward heavier and larger particulates.
- Do not underfill the sampler container (Appendix A4-A). Underfilling will result in a sample that is not isokinetically collected because the maximum transit rate has been exceeded.
- If the required volume cannot be collected, use the EDI method to obtain discharge-weighted samples.

d. Inspect each subsample as it is collected, looking for overfilling or underfilling of the sampler container and (or) the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. **If you note any of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.**

e. Move sampling equipment to the next vertical. Maintain the selected transit rate. The volume of the subsample can vary considerably among verticals. Subsamples can be collected at several verticals before emptying the sampler container, as long as the maximum volume of sample in a bottle or bag sampler has not been exceeded. If the container is overfilled, it is necessary to resample.

> TECHNICAL NOTE: The tables in Appendix A4-A apply to the first complete round-trip transit starting with an empty sampler container. These tables cannot be used if the sampler is not emptied between verticals.

f. Continue to the next vertical until no more samples can be collected without overfilling the sampler container. Empty the subsample into a field-rinsed churn or cone splitter and repeat sample collection in the same manner until subsamples have been collected at all the verticals.

- If the total volume of the subsamples to be collected will exceed the operational capacity of the churn, select from the following options: use either a sampler with a smaller bottle or a bag sampler with a smaller nozzle; or use a cone splitter; or use the EDI method, if appropriate.
- To ensure that all particulates are transferred with the sample, swirl the subsample gently to keep particulates suspended and pour the subsample quickly into the churn or cone splitter.
- Sample EWI verticals as many times as necessary to ensure that an adequate sample volume is collected as required for analysis, **but sample at each vertical an equal number of times.** (The composite cross-sectional sample will remain proportional to flow at the time of sampling.)
- If flow is stable during sampling, then multiple samples can be collected at each vertical during a single traverse along the cross section. If flow is changing, however, study objectives should determine whether to collect multiple samples at each vertical during a single traverse or to collect one sample at each vertical during multiple traverses along the cross section. Document on field forms the method used.

g. Record the following information after all samples have been collected:

- Sampling end time.
- Ending gage height.
- All field observations and any deviations from standard sampling procedures.

Step 5. Process Samples ➜ Refer to NFM 5.

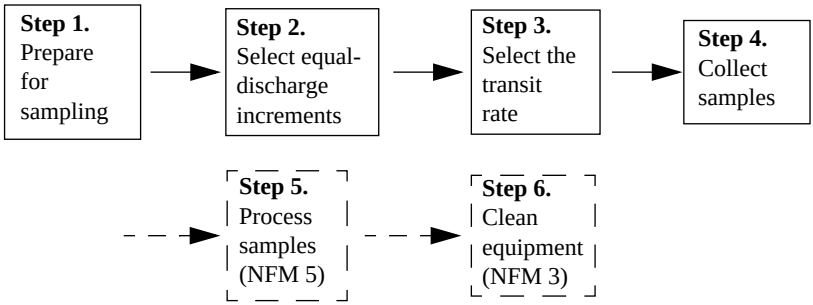
Step 6. Clean Equipment ➜ Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse sampler components with deionized water before they dry and place them into a plastic bag for transporting to the office laboratory to be cleaned.
- If the sampler will be reused during the field trip, rinse the components with DIW while still wet from sampling and then field-clean while at the sampling site using the prescribed procedures (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place the cleaned sampler into a plastic bag and seal for transport to the next site.

Equal-discharge-increment (EDI) method

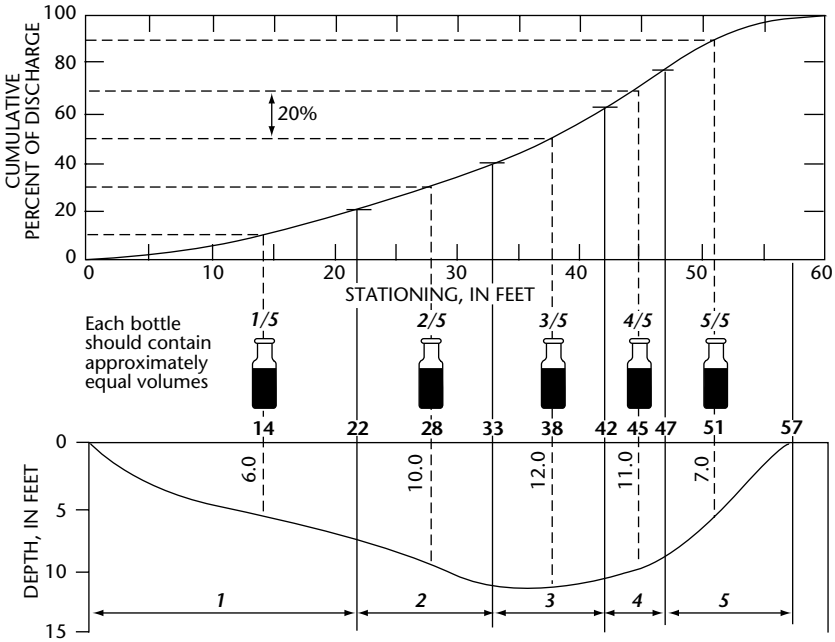
The objective of the EDI method is to collect a discharge-weighted sample that represents the entire flow passing through the cross section by obtaining a series of samples, each representing equal volumes of stream discharge. The EDI method requires that flow in the cross section be divided into increments of equal discharge. Equal-volume, depth-integrated samples are collected at the centroid of each of the equal-discharge increments along the cross section (fig. 4-3). Centroid is defined as that point in the increment at which discharge is equal on both sides of the point.

Guidelines for the EDI sampling method



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Example: Sampler D77; nozzle size, 5/16 inches ID; 3 Liter sample bottle; width 57 feet; maximum depth 12 feet; maximum velocity, 5.0 ft/s; width of section containing 20 percent of flow is variable, 5 to 22 feet; 20 percent of flow per section will give 5 sampling verticals; transit rate variable, 0.3 to 1.7 ft/s.



Sampling vertical bottle/ number	Percent discharge	Increment centroid from left edge of water, in feet	Increment depth, in feet	Velocity, in feet per second	Transit rate to give 2.7 liters, in feet per second
1/5	20	14	6	2.5	0.16
2/5	20	28	10	3.0	.33
3/5	20	38	12	3.1	.41
4/5	20	45	11	6.1	.72
5/5	20	51	7	4.8	.37

Figure 4-3. Equal-discharge-increment method for collection of water samples (modified from Bruce Ringen, U.S. Geological Survey, written commun., 1978).

Step 1. Prepare for sampling for inorganic and organic analytes.[8]

a. Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle in a location and direction so as to prevent sample contamination from vehicle emissions.

b. Assemble equipment needed and set up a clean work space.

- **Organic compounds**. Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics other than fluorocarbon polymers.**
- **Inorganic constituents**. Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
- **Microbiological analyses**. Collect samples for microbiological analyses using equipment and techniques described in NFM 7.

Step 2. Select the number and location of equal-discharge increments.

The number and location of equal-discharge increments should not be determined arbitrarily. Selection of increments for a sampling site is governed by factors described in a, d, and e below.

a. Visually inspect the stream from bank to bank, observing velocity, width, and depth distribution, as well as apparent distribution of sediment and aquatic biota along the cross section. Document location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other obstructions along the cross section.

b. Determine stream width from a tagline or from distance markings on bridge railings or on a cableway.

c. At sites with little sampling history—measure, record, and review the cross-sectional variation of field measurements (for example, specific electrical conductance, pH, temperature, and dissolved oxygen).

[8]Preparations for water sampling are described in NFM 1, 2, and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling, and NFM 9 for field safety.

d. Measure discharge at the cross section to be sampled or use an existing EDI graph prepared from current or historical discharge measurements (fig. 4-3) (Edwards and Glysson, 1998). An existing EDI graph can be one prepared for the site that shows, for example, cumulative discharge or cumulative percent of discharge versus stationing.

e. Determine volume of discharge that will be represented in each EDI, based on data objectives for the study, variation in field measurements, flow and stream-channel characteristics along the cross section, and volume of sample required for analyses of target analytes.

f. Divide the cross section into equal-discharge increments.

- When determining the number of increments to be sampled, keep in mind that the subsample collected at the centroid of each EDI must represent the mean streamflow measured for that increment. If mean streamflow for the increment is not represented, increase the number of increments by decreasing the volume represented by each discharge increment until the mean streamflow value for the increment is represented.
- As a guide, a minimum of 4 sampling increments is recommended; the number of increments is usually less than 10.

g. Determine the location of the centroid of flow within each increment from the discharge measurement by (1) constructing a curve using cumulative discharge or cumulative percentage of discharge (fig. 4-3) plotted against cross-section stationing, or (2) determining EDI locations directly from the discharge measurement sheet (fig. 4-4; an explanation of this method and definition of midpoint are described in Edwards and Glysson, 1998.) Centroid-of-flow locations also can be determined from an EDI graph, as described below and in the TECHNICAL NOTE that follows the example below.

Station: 11482500 Redwood Creek at Orick, CA

Far-Mid Point	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted for hor. angle or	Area	Discharge Q	Discharge ΣQ	
4	0	4	0	.6	LE	W	0			0	0	0	
12	8	8	1.00		30	47	1.41			8.0	11.3	11.3	
20	16	8	1.80		30	44	1.51			14.4	21.7	33.0	
26	24	8	2.00		50	44	2.50			16.0	40.0	73.0	62.2
28	32	8	2.00		60	45	2.92			16.0	46.7	119.7	
36	40	8	2.30		50	48	2.29			18.4	42.1	161.8	
44	48	8	2.25		40	44	2.00			18.0	36.0	197.8	186.6
50	56	8	2.25		40	40	2.20			18.0	39.6	237.4	
52	64	8	2.30		40	40	2.20			18.4	40.5	277.9	
60	72	8	2.30		50	45	2.44			18.4	44.9	322.8	311.0
68	80	8	2.20		40	45	1.96			17.6	34.5	357.3	
74	88	8	2.00		40	43	2.05			16.0	32.8	390.1	
76	96	8	1.90		50	47	2.34			15.2	35.6	425.7	
84	104	8	2.00		40	42	2.10			16.0	33.6	459.3	435.4
92	112	8	2.00		40	40	2.20			16.0	35.2	494.5	
100	120	8	1.90		30	43	1.54			15.2	23.4	517.9	
102	128	8	1.80		40	40	2.20			14.4	31.7	549.6	
108	136	8	1.70		50	44	2.50			13.6	34.0	583.6	559.8
116	144	8	1.60		50	44	2.50			12.8	32.0	615.6	
124	152	8	1.00		20	54	.827			8.0	6.6	622.2	
132	160	4	0	.6	RE	W	0			0	0	622.2	
134													
140													
148													
156													
160													
	160	160								290.4	622.2		

EDI Centroid Location EDI Cumulative Discharge

Figure 4-4. Discharge-measurement field notes used to determine the equal-discharge-increment centroid locations based on cumulative discharge and far-midpoint stationing (from Edwards and Glysson, 1998, p. 42).

Example:

In this example, each EDI equals 20 percent of discharge.

i. If the stream cross section will be divided into five equal-discharge increments, divide stream discharge by five to determine the discharge increment.

ii. Locate the centroid of the initial EDI where cumulative discharge equals half the discharge increment (10 percent). This is the location of the vertical from which the first subsample is collected.

iii. Locate each of the remaining centroids (four in this example) by adding the discharge increment (20 percent) to the previous centroid discharge (20 + 10 = 30) and determining where that cumulative discharge occurs along the cross section.

iv. The EDI centroids will correspond to locations of 10, 30, 50, 70, and 90 percent of the cumulative discharge along the cross section. In figure 4-3, these percentages of cumulative discharges correspond to locations at 14, 28, 38, 45, and 51 ft from the left edge of the water, whereas in figure 4-4, the centroid locations of the equal-discharge increments are at 26, 50, 74, 102, and 134 ft.

TECHNICAL NOTE: If the stream channel is stable at the cross section to be sampled, graphs of cumulative discharge or percentage cumulative discharge at various stages can be based on historical discharge measurements. Location of EDI centroids can be determined from these EDI graphs so that discharge measurements do not have to be made before each sampling. Linear interpolation based on discharge can be made between curves for different discharges on the EDI graphs. **EDI graphs require periodic verification by being compared to recent discharge measurements.**

Step 3. Select the transit rate.

a. Determine the sampling depth and the mean stream velocity at the centroid of each equal-discharge increment.

b. Determine the transit rate for each centroid that will yield subsamples with approximately the same volume (within 10 percent) using sampling depth, mean stream velocity, and information in Appendix A4-A. When compositing subsamples, the minimum volume for every equal-discharge increment is the minimum volume for the deepest vertical.

Guidelines for selecting the transit rate for EDI sampling
• Collect samples of equal volumes at each centroid. This is required for EDI if the sample will be composited (fig. 4-3). Generally, transit rates vary from centroid to centroid in order to collect equal volumes. • Keep the transit rate unidirectional, constant, and within the isokinetic transit range of the sampler when collecting isokinetic samples at each centroid. • **Do not exceed the maximum transit rate** (Appendix 4A-4). The maximum transit rate will be exceeded if the minimum sample volume associated with stream velocity and the selected nozzle and bottle size is not collected. Exceeding the maximum transit rate will affect the concentration of particulates ≥ 0.062 millimeters.

Step 4. Collect samples.

The procedures are the same whether you are wading or using a reel-and-cable suspension method. **Use *CH/DH* techniques, as required (section 4.0.1), and implement safety procedures (NFM 9).**

- ▶ Collect microbiological samples using equipment and techniques as described in NFM 7.
- ▶ Collect subsamples at EDI centroids as many times as necessary to ensure collection of sufficient sample volume for analysis. If the sample is to be composited, care must be taken to obtain approximately the same total volume (± 10 percent) from each EDI centroid so that the composited cross-sectional sample will be proportional to flow at the time of sampling.
- ▶ Stay within the isokinetic transit-rate range of the sampler at each centroid. If flow velocity is less than the isokinetic transit-rate range of the sampler, a discharge-weighted sample still can be obtained by collecting equal volumes at each centroid; however, this sample will not be isokinetic.

a. Move sampling and support equipment to the centroid of the first increment to be sampled. Field rinse the sampling equipment (section 4.0.2) and record sampling start time.

b. Read and record the starting gage height.

c. Lower the sampler at the predetermined transit rate until slight contact is made with the streambed.

- **Do not pause upon contacting the streambed.** Raise the sampler immediately at a constant transit rate to complete the vertical traverse. The descending transit rate does not have to equal the ascending transit rate, but each rate must be unidirectional, constant, and within the isokinetic transit range of the sampler.
- Take care not to disturb the streambed with the sampler. Disturbing the streambed could cause bed material to enter the nozzle, resulting in erroneous data.
- Ensure that the sampler container has not overfilled. Overfilling will result in enrichment of the sample with heavy particulates due to secondary circulation of water through the sampler (from nozzle through air exhaust). This enrichment will result in an artificially increased sediment concentration and will bias particle-size distribution towards heavier and larger particulates.

d. Inspect each subsample, looking for overfilling and (or) the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If you note either or both of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.

e. Ensure that the sampler container is not underfilled (that the minimum volume indicated in Appendix A4-A has been collected). Underfilling will result in a subsample that is not isokinetically collected—usually because the maximum transit rate has been exceeded.

f. Depending on study objectives, either process and (or) analyze the subsample collected at the initial centroid as a separate sample, composite this subsample with other subsamples collected along the cross section, or split the subsample for further processing.

- If the total volume of the subsamples that will be collected will exceed the operational capacity of the churn or cone splitter, decrease the number of increments or use an appropriate sampler with a smaller bottle or with a bag with a smaller nozzle.
- Ensure that all particulates in the sampler bottle or bag are transferred with the sample by swirling the sample gently to keep particulates suspended, and quickly pouring the sample into the churn or cone splitter.

g. Move equipment to the next vertical.

- Determine the transit rate for this vertical. If the subsamples are composited, the total volume collected at each centroid must be equal.
- Repeat procedures, steps 4 c-f.
- Repeat this process at the remaining verticals along the cross section.

h. Record the following information after all samples have been collected:

- Sampling end time.
- Ending gage height.
- All field observations and any deviations from standard sampling procedures.

Step 5. Process samples ➜ Refer to NFM 5.

Step 6. Clean equipment ➜ Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse the components with deionized water before they dry and place them into a plastic bag for transport to the office laboratory to be cleaned.
- If the sampler will be reused during the field trip, rinse the components with DIW while still wet from sampling, and then follow the prescribed cleaning procedures while at the sampling site (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place cleaned sampler into a plastic bag and seal for transport to the next site.

Single vertical at centroid-of-flow (VCF) method

The VCF method for collecting water samples is identical to the EDI method except that there is one centroid of flow for the stream cross section and therefore only one vertical is sampled. To use this method, the section must be well mixed vertically and laterally with respect to concentrations of target analytes.

Guidelines for the VCF method

1. Measure discharge along the cross section where sampling is to be done. (This is not necessary if the section is stable and accurate historical discharge measurements are available.)

2. Locate the centroid of flow from the discharge measurement.

   - Either (a) construct an EDI graph using cumulative discharge or cumulative percentage of discharge plotted against cross-section stationing (for example, in fig. 4-3, the centroid location is station 38, which corresponds to 50 percent of cumulative flow), or (b) determine centroid location directly from the discharge measurement sheet (for example, in fig. 4-4, the centroid location is station 74).

   - EDI graphs of cumulative discharge at various stages can be based on historical discharge measurements if the stream channel is stable at the cross section to be sampled. The location of centroids can be determined from these EDI graphs so that discharge measurements do not have to be made before each sampling. **EDI graphs require periodic verification.**

3. Examine the cross section for uniformity of appearance.

4. Measure the cross-sectional variation of field measurements (such as specific electrical conductance, pH, temperature, and dissolved oxygen) at sites with little sampling history. Record and review variations along the cross section.

5. Evaluate data from steps 1–4 to decide if the VCF method is appropriate. Use either the EDI or the EWI sampling method if streamflow, field-measurement, or chemical-analysis data do not confirm that the stream section is well mixed vertically and laterally.

6. If the VCF method is used, follow steps 3 and 4 of the instructions for the EDI method for selecting transit rate and collecting samples.

7. **Process samples ➜** Refer to NFM 5.

8. **Clean equipment ➜** Refer to NFM 3.

Nonisokinetic Dip, Discrete, and Pump Sampling Methods 4.1.1.B

Most nonisokinetic samplers cannot be used to collect representative discharge-weighted samples from streams transporting sand-size or larger particulates. These samplers have important uses for unattended stream sampling and for sampling to determine constituent occurrence and distribution, but they have limited value for collecting samples used to calculate constituent discharge.

Guidelines for nonisokinetic sampling methods
Use nonisokinetic sampling methods when: • Velocity of flow is so high that an isokinetic sampler cannot be lowered through the vertical properly and safely. • Extreme low-flow conditions render use of an isokinetic sampler impractical. For example, when water depth is equal to or less than that of the unsampled zone or when stream velocity is less than the minimum velocity requirement for an isokinetic sampler (1.5 ft/s for bottle samplers, 3 ft/s for bag samplers). • Automatic pumping samplers are needed for specific situations; for example, time-dependent regulatory monitoring, sampling at remote sites, or sampling of floods or urban runoff when discharge is rapidly changing and a large number of samples are needed from several locations within a relatively short time. • Periods of extreme cold cause the nozzle or air-exhaust vent to freeze, rendering isokinetic, depth-integrating samplers inoperable. • Study objectives dictate use of nonisokinetic sampling methods.

Three nonisokinetic sampling methods most commonly used are the dip (weighted-bottle), discrete, and pump methods. Ward and Harr (1990) and Edwards and Glysson (1998) provide detailed information on these sampling methods. General instructions are provided below.

- **Dip sampling method**. Dip sampling involves dipping a narrow-mouthed bottle into a water body. Dip sampling is not recommended for discharge-weighted sampling when it is possible to obtain a depth-integrated, isokinetic sample. **The error introduced by dip sampling can be significant if the target analytes are sorbed onto suspended materials that are not uniformly distributed along the cross section.** Care must be taken to avoid collecting particulates that are resuspended as the result of wading or bumping the sampler on the streambed.
  - To collect a dip sample in water that is too shallow to submerge an isokinetic, depth-integrating sampler, wade to where the sample(s) will be collected and immerse a hand-held, narrow-mouth bottle at the centroid of flow or at multiple locations along a cross section.
  - To sample with a hand-held bottle, stand downstream of the bottle while it is being filled.
  - To collect a dip sample where water is too deep to wade, lower a weighted-bottle sampler at the centroid of flow or at multiple locations along a cross section.
- **Discrete sampling method**. Discrete (point) sampling involves either (1) lowering a sampler to a specified depth and collecting a sample by first opening, then closing the sampler, or (2) using a single-stage sampler, which fills when stream stage rises to a predetermined height.
  - Thief-type samplers are the most common point samplers used for collecting water-quality samples (NFM 2). Although these samplers are designed primarily to sample still waters, they can be adapted for slow-flowing water by attaching them to a weighted line. Samples can be collected at the centroid of flow or at multiple verticals and at selected depths along the cross section.
  - Isokinetic point samplers (for example, the P-61 and P-63 described in Edwards and Glysson, 1998) are available for collecting samples for suspended-sediment concentration and particle-size determination, and for selected chemical constituents. **The P-61 and P-63 samplers are not suitable for collecting samples for trace-metal analyses.**

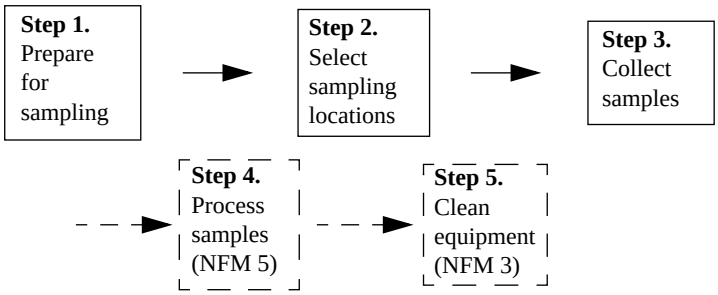
- Single-stage samplers, such as the U-59 (NFM 2) are useful for collecting samples for analysis of sediment and selected chemical constituents at stations located on streams or other locations susceptible to flash floods or where it is otherwise difficult to reach a station to manually collect samples. Before single-stage samplers can be installed, some knowledge of the seasonal stage characteristics of the stream is needed so that an appropriate sequence of samples can be obtained for a given storm season. The stream-stage and flow-velocity characteristics not only affect the design with respect to the vertical spacing of the samplers but also the support necessary for the samplers. These samplers have not been certified as appropriate for collection of uncontaminated trace-element samples.

▶ **Pump sampling method**. Pump sampling involves either suction lift or submersible pump systems designed to collect water-quality samples (NFM 2). Pump systems can be portable or can be permanently installed and automated for sampling.

- Pump samplers generally are not used to collect isokinetic samples because of the difficulty in controlling the sample velocity through the sampler intake relative to the flow rate and direction of suspended particulates in the stream.
- Portable-pump samplers generally are used to collect a point sample by lowering the pump to a selected depth.
- A portable pump also can be used to collect a nonisokinetic, depth-integrated sample by continuous pumping at a constant rate as the intake is being lowered through the vertical.

Collection of useful data, especially with the use of automated pumping samplers, requires intensive planning and quality assurance, including careful site selection, selection of the type and construction material of the sampler, a review of historical hydrologic information, and collection of an adequate number and types of quality-control samples. The physical, chemical, and biological characteristics of the cross section, study objectives, and pump limitations must be considered when determining how and where to collect samples.

Guidelines for nonisokinetic sampling methods



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Step 1. Prepare for sampling for inorganic and organic analytes.[9]

a. Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle in a location and direction so as to prevent sample contamination from vehicle emissions.

b. Assemble equipment and set up a clean work space.

- **Organic compounds**. Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics unless they are fluorocarbon polymers.**
- **Inorganic constituents**. Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
- Collect samples to be analyzed for sediment concentration and (or) particle-size distribution using a separate set of clean sample bottles. Sediment samples generally are not field composited.
- Collect bacteria samples using equipment and techniques described in NFM 7.
- Calibrate field instruments as described in NFM 6.

[9]Preparations for water sampling are described in NFM 1, 2, and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling, and NFM 9 for field safety.

Step 2. Select sampling locations.

Review data objectives to ensure they will be met at the sampling location(s) selected. If discharge-weighted samples are needed and the stream section is well mixed with respect to target analytes, locate multiple sampling points along the cross section using the EDI method.

a. Measure discharge at the cross section where samples will be collected.

b. At sites with very little sampling history, measure the variation within each field measurement (specific electrical conductance, pH, temperature, and dissolved oxygen) along the cross section and review these data.

c. Locate the centroid of flow if distribution of streamflow and the field-measurement data indicate that the section is well mixed (refer to the description of the VCF sampling method at the end of section 4.1.1.A, p. 48).

Step 3. Collect samples.

By applying EDI sampling methods and collecting equal-volume samples at the centroid of each equal-discharge increment, a sample can be collected that is discharge weighted but that is not isokinetic.

Using CH/DH techniques, as required (section 4.0.1):

a. Move sampling and support equipment to the first sampling location. Field rinse equipment (section 4.0.2).

b. Record starting gage height and sampling start time.

c. Lower field-rinsed sampler using the method selected.

- If a vertical traverse is made to collect the sample, **do not pause when contact with the streambed occurs**, but raise the sampler immediately until the traverse is completed. Take care not to disturb the streambed with the sampler, as bed material entering the sampler results in erroneous data.
- If a discrete sample is to be collected, lower the sampler to the desired depth, then sample.
- If a pump is used to collect a sample, lower the pump intake to the desired depth and pump about three sample-tubing volumes to field rinse sample tubing before collecting the sample.

d. Move to the next vertical (if more than one vertical will be sampled along the cross section).

   i. Record the time and repeat sample collection as described in step 3c above.

   ii. Inspect each sample, looking for anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If such a condition is observed, discard the sample, making sure there are no residual particulates left in the container, and resample.

   iii. Depending on data objectives, either composite the samples collected or set aside each sample to be independently processed and analyzed.

   - If pumped samples will be composited, pump the samples directly into the churn splitter.
   - If transferring the subsample to a churn or cone splitter, ensure that all particulates in the sampler are transferred with the sample by swirling the sample gently to keep particulates suspended and pouring the sample quickly into a sample splitter.

e. After all the samples have been collected:

   - Record sampling end time and gage height. For automated samplers, record beginning and ending dates and times for the sampling period.
   - Retrieve samples from automated pumping samplers at the earliest possible time to reduce the chance of chemical or biological alteration of the sample. (Automatic samplers with refrigeration are available to help maintain sample integrity.) Samples collected by automatic samplers generally are composited.
   - Document all field observations and any deviations from standard sampling procedures.

Step 4. Process samples ➜ Refer to NFM 5.

Step 5. Clean equipment ➜ Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse the sampler components with deionized water before they dry and place them in a plastic bag for transport to the office laboratory to be cleaned.
- If the sampler will be reused during the field trip, rinse the components with DIW while still wet from sampling and then field-clean while at the sampling site using the prescribed procedures (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place the cleaned sampler into a plastic bag and seal for transport to the next site.

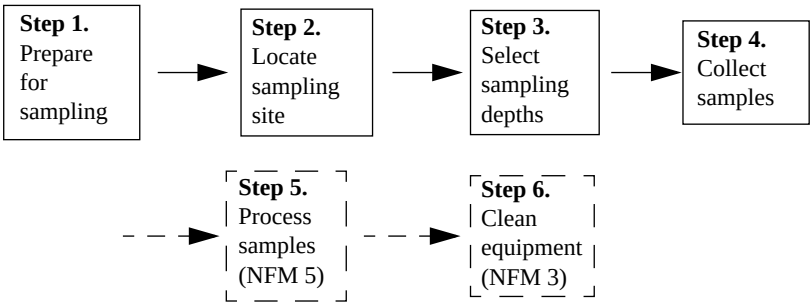
4.1.2 STILL-WATER SITES

In still water, samples generally are collected at multiple sites and at multiple depths. The probability is very small that any still-water body (lake, reservoir, pond, lock, storage pool) is relatively homogeneous with regard to any water-quality characteristic. Therefore, a single site or sampling point generally is not adequate to describe the physical and chemical properties of the water body, or the distribution and abundance of the inhabiting biological community. The number of sampling sites and the depths where samples will be collected depend on study objectives and the physical, chemical, and biological characteristics of the water body (Ward and Harr, 1990).

Thief-type samplers usually are used to collect still-water samples; however, pumping samplers also can be used. A disadvantage of pumping a sample is that if a thin stratum of water is being sampled, water can move radially from unknown depths and distances into the pump.

- Samples must be collected at a known depth.
- Sample integrity must be maintained to the degree possible while samples are being brought to the surface for further processing.

Guidelines for sampling at still-water sites



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Step 1. Prepare for sampling of inorganic and organic analytes.[10]

a. Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle so as to prevent sample contamination from emissions.

b. Assemble equipment and set up a clean work space.

- **Organic compounds**. Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics other than fluorocarbon polymers.**
- **Inorganic constituents**. Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
- **Microbiological analyses**. Collect microbiological samples using equipment and techniques described in NFM 7.

Step 2. Locate sampling site.

a. Locate the first sampling site (vertical section) and maintain a sampling platform position at the site.

b. Record depth to bottom.

Step 3. Select sampling depths.

a. Make field measurements (such as specific electrical conductance, pH, temperature, and dissolved oxygen) in situ to obtain a vertical profile of field-measurement variation.

b. Measure light penetration (if applicable).

c. Select and record sampling depth(s) based on study objectives and the variation in field measurements for the vertical.

[10]Preparations for water sampling are described in NFM 1, 2, and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling, and NFM 9 for field safety.

Step 4. Collect samples.

Field rinse sampling equipment first (section 4.0.2). Collect samples by using the procedures listed below under Step 4A for a thief-type sampler and under Step 4B for a pump sampler.

Step 4A. Thief-type sampler.

The instructions listed below are for samplers that operate with an open/close mechanism. If the sampler operates as a point-source bailer, follow a and c-g below. Pulling the bailer up will trigger the upper check valve to seal off the sample from the water overlying the targeted depth.

a. Lower opened sampler to the desired depth while minimizing disturbance of the water column.

b. Isolate the sample by activating the mechanism that closes the sampler.

c. Raise the sampler from the water body.

d. Dispense sample to sample bottle or compositing/splitting device using *CH/DH* techniques, as required or recommended:

- If using a bailer, drain sample through the bottom-emptying device.
- If sample compositing and (or) splitting is required, ensure that all particulates in the sampler are transferred with the sample by swirling the sample gently to keep particulates suspended and pouring the sample quickly into the churn or cone splitter.

e. Repeat the instructions in Step 4A a -d if more sample is needed from the same depth for that vertical section.

f. Repeat the instructions in Step 4A a -e for each depth to be sampled in that vertical section. If a second sample from a different depth or vertical section will be composited, either (1) clean and field rinse the splitter after processing the first sample and before collecting the second sample, or (2) use another clean splitter.

g. Move to the next site if another vertical section will be sampled. Repeat Step 4A a -f.

Step 4B. Pump sampler.

a. Lower the pump or pump-sample tubing (attached to a weighted line) to the desired sampling depth.

b. Turn on the pump and pump about three sample-tubing volumes to field-rinse the pump, tubing, and other sample-collection or -processing equipment. Discard rinse water.

c. Direct sample flow into collection container(s) until sufficient sample volume has been collected.

d. Repeat Step 4B a - c if another depth and (or) vertical section is to be sampled. If a second sample from a different depth or vertical section will be composited, either (1) clean and field rinse the splitter after processing the first sample and before collecting the second sample, or (2) use another clean splitter.

Step 5. Process samples ➜ Refer to NFM 5.

Step 6. Clean equipment ➜ Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse the sampler components with deionized water before they dry and place them in a plastic bag for transporting back to the office laboratory to be cleaned (NFM 5).
- If the sampler will be reused during the field trip, rinse the components with DIW while still wet from sampling and then field-clean while at the sampling site using the prescribed procedures (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place the cleaned sampler into a plastic bag and seal for transport to the next site.

GROUND-WATER SAMPLING: PREPARATIONS AND PURGING METHODS AT WATER-SUPPLY WELLS AND MONITORING WELLS 4.2

By **Jacob Gibs and F.D. Wilde**

Collecting samples of ground water that accurately represent aquifer conditions requires sampling appropriate wells using equipment and methods that maintain the integrity of the sample with respect to the physical, chemical, and biological characteristics of interest. Ground-water sample collection involves specific preparations, such as measuring the water level in a well and purging the well of standing water. This chapter (NFM 4) primarily addresses the activities up to the point that the ground-water sample enters a collection/processing chamber. Because purging, sample withdrawal, and sample processing form a continuous process, the information provided in this chapter overlaps somewhat with that in NFM 5. NFM 5 addresses the required and recommended procedures for filling bottles with a water sample (raw or filtered), sample preservation, and other sample-processing activities.

The generic information provided below for withdrawing water from wells is followed by specific information and procedures for sampling from supply wells (section 4.2.1) and monitoring wells (section 4.2.2).

Considerations for collecting representative ground-water samples

Consideration must be given to well type, well construction, sampling equipment, and well-purging and sampling methods to ensure that a representative sample is collected.[11] Field personnel should be aware of the factors that can affect the quality of ground-water samples and are instructed to use appropriate contamination prevention techniques (tables 4-1 and 4-2). It is imperative to review the most recent analyses of blank samples

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

collected through the equipment to be used for sampling before field work begins, and to collect other types of quality-control (QC) samples as a routine part of field work (section 4.3 and Appendixes A4-B and A4-C).

Review any previously collected QC data before field work begins.

- **Well type.** Check the type of well(s) to be sampled before beginning field work. Equipment and sampling methods can differ substantially, depending on the well type (NFM 1).
  - **Supply wells** are designed for domestic, public, industrial/commercial, and irrigation use and commonly are constructed using methods and materials that can affect sample chemistry. (NFM 1 and Lapham and others, 1997, describe selection criteria for supply wells.) Pumps installed in supply wells generally deliver a large volume of water that is subsampled for water quality.
  - **Monitoring wells** are designed and installed principally for the collection of water-quality samples and related data. Samples from monitoring wells are collected either with portable, low-capacity pumps or with other types of sampling devices designed for water-quality work. Sampling devices can be dedicated for use at a well and (or) can be installed permanently or semipermanently.
- **Well construction.** Periodically check the integrity of the well's construction and hydraulic communication with the aquifer: inspect casing with a televiewer, note any changes in depth-to-well-bottom measurements, and run slug tests or aquifer tests (Lapham and others, 1997). Check well integrity only after sample collection is complete or during a nonsampling site visit to avoid stirring up particulates that could cause a bias in analysis of trace metals, polychloride biphenyls (PCBs), or other analytes that tend to associate with particulates. If water from the well is laden with particulates, the well should be redeveloped or purged until turbidity values return to background or near-background levels (normally less than 5 NTU, the threshold for visible turbidity).

- To collect samples that represent a specific zone of an aquifer, the well must be in hydraulic communication with the water-bearing unit of interest and must be isolated or sealed from overlying and underlying units.
- Determine the aquifer interval(s) that yield significant contribution of flow if collecting samples in media with strongly defined paths of preferential flow, such as in fractured rock.
- Review guidelines in NFM 1 and Lapham and others (1997) for selecting the materials, length, and diameter of the well screen and casing, well completion method, and well development method.

▶ **Sampling equipment.** Select and prepare equipment using the guidelines and protocols described in NFM 2, 3, 5, and 6.

- The sample-wetted parts of the equipment must be constructed of materials that will not contaminate the sample or otherwise affect ambient concentrations of target analytes.
- All sampling equipment must be precleaned and quality assured. Equipment-blank analyses should confirm that the equipment to be used is not a source of contamination with respect to concentrations of target analytes. Document in field notes the cleaning and QA procedures used, along with the analytical results for equipment-blank data.
- A flow-splitting manifold constructed of noncontaminating materials is recommended for use at the wellhead for directing pumped sample flow (fig. 4-5).
- The sample tubing should extend into a processing chamber or glove box to avoid sample contamination from the atmosphere. Set up sample chambers before beginning sample collection (a flowthrough chamber for field measurements and processing and preservation chambers for sample filtration and preservation, respectively).

Refer to NFM 6 for detailed instructions on field measurements for conductivity, pH, Eh, temperature, turbidity, dissolved oxygen, and alkalinity.

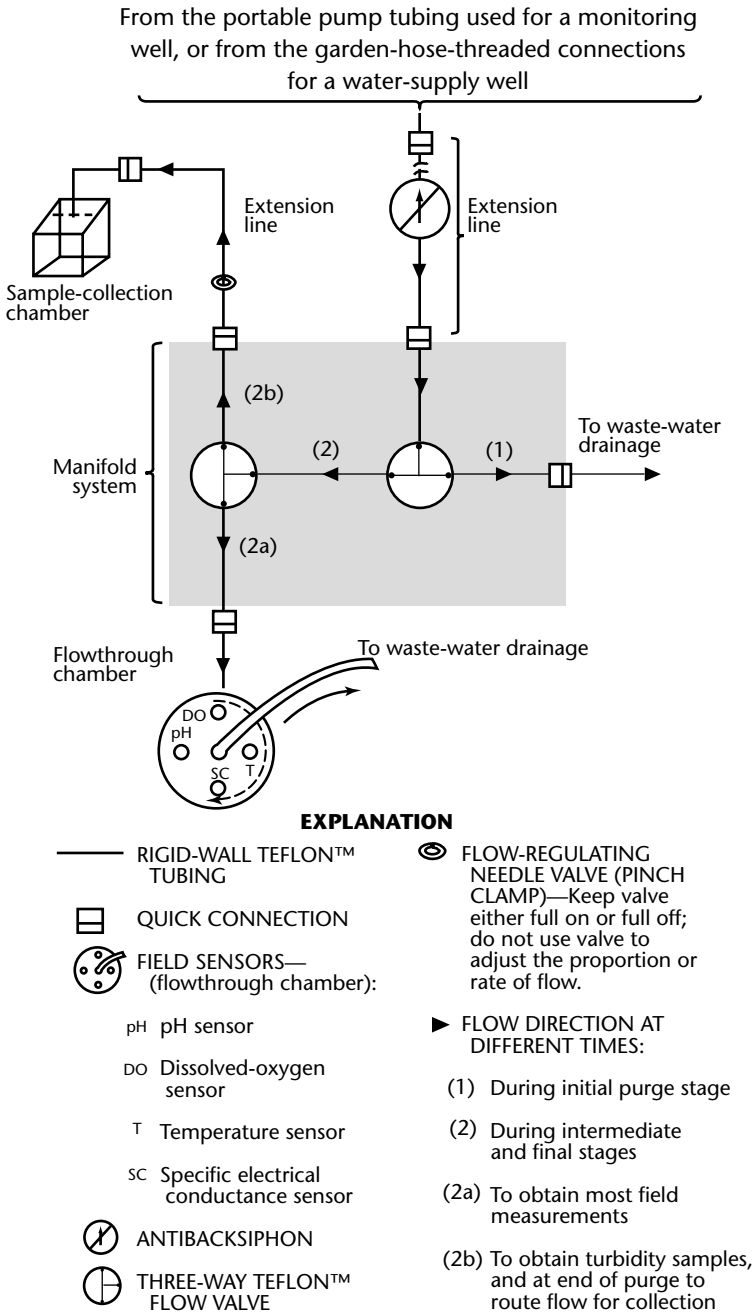


Figure 4-5. Example of a manifold used for well purging and sample collection (modified from Koterba and others, 1995).

✓	Checklist of equipment and supplies used for site setup and sampling at wells
	Antibacksiphon device (one-way or check valve)
	Flow-splitting valve(s) (two- or three-way manifold)
	Keys (for locked facilities)
	Photoionization detector (PID or sniffer)
	Tarp or plastic sheeting to place around well to keep equipment clean
	Tubing to direct waste discharge offsite or into sample container
	Sample processing and preservation chambers in which samples are bottled and treated, respectively
	Airtight flowthrough chamber for field-measurement sensors
	Sample tubing (precleaned, several lengths)
	Sampling device(s) (precleaned, portable equipment or other, as appropriate)
	Stopwatch and calibrated bucket to measure pumping rate
	Threaded fittings, male/female, such as hose-type connectors (precleaned)
	Tools (such as wrenches to remove well cap)
	Water-level measurement equipment

- **Well-purging and sampling methods.** Before selecting and implementing the purging and sampling methods described below, consider how maintaining sample integrity (table 4-4) applies to your specific study and site, making sure to consider:
  - Type and construction of well, and the hydraulic conditions and subsurface geochemistry at the site (Lapham and others, 1997).
  - Study requirements to ensure and determine data quality for target analytes (section 4.3).
  - Specific protocols needed to meet program or study objectives that could require modification of standard methods. Document any deviations from recommended sampling procedures and record field observations in field notes.

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

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

Verify the well ID before sampling. Every well must be permanently labeled with its unique ID.

Offsite preparations[12]

Before leaving for the field site, review the types of environmental and QC samples to be collected (check section 4.3 for QC information). QC samples require additional equipment and supplies.

- Prepare the field forms that will be needed (for example, water-level, purging, field-measurement, analytical services request, and chain-of-custody forms). Fill out as much information as possible, including the equipment to be used and numbers and types of samples to be collected.
- Check equipment requirements (NFM 2). When assembling the equipment, test that equipment is in good working condition. Take backup equipment, as appropriate.
  - **Organic-compound samples.** Use fluorocarbon polymer, glass, or metal for any equipment components that will be in contact with samples to be analyzed for organic compounds. Do not use plastics other than fluorocarbon polymers.
  - **Inorganic-constituent samples.** Use fluorocarbon polymer or other relatively inert and uncolored plastics or glass for any equipment components that will be in contact with samples to be analyzed for inorganic constituents. Do not use metal or rubber components for trace-element sampling. Stainless-steel sheathed pumps are generally acceptable, but could leach low concentrations of chromium, molybdenum, nickel, and vandium to the sample. **Collect an equipment blank before sampling to demonstrate the acceptability of the data to be collected.**
- Set up a clean workspace (usually in the water-quality field vehicle) and the sample-processing and -preservation chambers. Place the filter unit and other necessary supplies for sample collection and processing into the processing chamber.

[12]Preparations for water sampling are describe in NFM 1, 2, and 3. Consult NFM 5 for sample processing, NFM 6 for field measurements, NFM 7 for biological indicators, NFM 8 for bottom-material sampling, and NFM 9 for field safety.

Measuring water levels

The static water level in a well is measured routinely before water samples are withdrawn from the well. Water-level-measurement procedures can differ for supply wells (section 4.2.1) and monitoring wells (section 4.2.2). Detailed procedures for various methods of measuring water levels are documented in U.S. Geological Survey (1980, p. 2-8) and additional information can be obtained from the USGS Office of Ground Water (http://water.usgs.gov/ogw).

- Procedures and equipment for water-level measurement can differ, depending on the type, construction, and design of a well.
- Document in field notes if oil is floating on the water table. Review your equipment-cleaning and sample-collection strategies and revise as needed if oil is present, to prevent contamination of samples. A dual-phase sonde can be used to determine the thickness of the oil layer, as well as the depth to water.
- Water-level measurement may not be possible or accurate in some supply wells (section 4.2.1). Record any measurement problem(s) on field forms.
- Continuous monitoring of water levels is recommended throughout purging of monitoring wells (section 4.2.2).
- Record discrete water-level measurements on field forms.

Purging the well while monitoring field measurements

Standard purge procedure involves removal of at least three well volumes of standing water while monitoring field measurements and water level as a function of time, pumping rate, and the volume of water removed (figs. 4-6 and 4-7). The low-flow (micropurge) and standard purging methods are discussed in the TECHNICAL NOTE below.

- Purging should not cause significant drawdown in monitoring wells; the purge procedure should be modified appropriately if substantial drawdown occurs. Ensure that purging is sufficient to remove water from the annular space surrounding the well casing.
- Field-measurement procedures are described in detail in NFM 6. Collection of water samples is not recommended from a well in which field measurements have not met stability criteria (fig. 4-7).
- **Exceptions to the three-well-volume rule.** Site characteristics or study objectives could require modification of the standard purge procedure by changing the number of well volumes removed or by changing or adding the types of field measurements and analyses. **Document the well-purging procedure used.** When standard purge volumes cannot be removed, (1) sufficient water must be withdrawn from the well to field rinse the sampler and sample tubing, and (2) field measurements must be monitored before collecting samples. Modify the standard purging protocol when:
  - A supply well to be sampled has been pumped continuously or long enough to have removed three casing volumes of water before sampling.
  - The sample-collection interval is sealed with packers (purge the packed interval).
  - Drawdown occurs rapidly but recovery to approximately 90 percent cannot be achieved before samples are collected.
  - Purging probably will disturb sediment at the bottom of the well because the water column is small.
  - The well to be sampled is equipped with a dedicated sampling device and the intake is within the open or screened interval.
  - A purge-minimization device (Schalla, 1996) or low-flow purging techniques are used.

TECHNICAL NOTE:

- **Low-flow (micropurge) purging** procedures are designed to minimize the volume of purge water and are applicable to some studies and sites at which the pump intake is to be located within the screened/open interval and a low rate of flow can be maintained without compromising sample integrity for the target analytes (usually unfiltered trace elements) (Kearl and others, 1992; Puls and Powell, 1992; Puls and Barcelona, 1996). The low-flow method requires either a permanently installed (dedicated) pump capable of low flow rates, or a waiting period of 24 hours after installing and before starting a portable pump.
- **Standard procedure** is to calculate a purge volume using the height of the water column to the bottom of the well, instead of the water-column height to the top of the screen. The greater volume minimizes effects on ground-water chemistry from (1) vertical and (or) horizontal exchange of water in the open or screened interval with the aquifer, and (2) diffusion of oxygen from air above the water column into the column of standing water within the open or screened interval. In addition, the length of the open or screened interval might not be known, while well depth can be measured onsite. The smaller the ratio of length of open or screened interval to total height of water column, the smaller the difference between the low-flow and standard procedures for calculating purge volume and possible effect on water chemistry.

C RULE OF THUMB: A sufficient volume has been purged from the well when the variability in sequentially monitored field measurements is within the prescribed criteria for stability.

Well volume = V = 0.0408 HD^2 = ___ gallons, where
V is volume of water in the well, in gallons,
D is inside diameter of well, in inches, and
H is height of water column, in feet

Purge volume = (n)(V) = _____ gallons, where
n is number of well volumes to be removed during purging

***Q* = estimated pumping rate = _____ gallons per minute**

Approximate purge time = (purge volume)/*Q* = _____ minutes

Well casing diameter (*D*)	Gallons per foot of casing
1.0	0.04
1.5	.09
2.0	.16
3.0	.37
4.0	.65
4.5	.83
5.0	1.02
6.0	1.47
8.0	2.61
10.0	4.08
12.0	5.88
24.0	23.5
36.0	52.9

Figure 4-6. Estimation of purge volume and purge time.

RECORD OF WELL PURGING

Date: _____ By: _____

STATION ID _____ STATION NAME _____

HEIGHT OF WATER COLUMN_____ DEPTH OF WELL_____

PUMP INTAKE (ft or m below MP): Start_____ End _____

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

_____

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

* Circle the unit used; MP, measuring point; LS, land surface; ft, feet; m, meter; °C, degrees Celsius; mg/L, miligrams per liter; gpm, gallons per minute; L/min, liters per minute.

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

V = volume of water in well, in gallons; D = inside well diameter, in inches; H = height of water column, in feet; n = number of well volumes to purge. Well volume is 0.16 gallons per foot for a 2-in. casing diameter.

FIELD MEASUREMENT	STABILITY CRITERIA[1]
pH	± 0.1 standard units
Temperature (T) (in degrees Celsius)	± 0.2°C (thermistor thermometer) ± 0.5°C (liquid-in-glass thermometer)
Specific electrical conductance (SC) (in microsiemens per centimeter at 25 °C)	± 5%, for SC ≤ 100 µS/cm ± 3%, for SC > 100 µS/cm
Dissolved-oxygen concentration (DO) (in milligrams per liter)	± 0.3 mg/L
Turbidity (TBY) (in nephelometric turbidity units or formazin turbidity units; FTU ≈NTU)	± 10%, for NTU < 100 Note: Ambient TBY is ≤ 5 NTU for most ground-water systems

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

Figure 4-7. Example of field form for a record of well purging.

Withdrawing the ground-water sample

If samples are being pumped, start sample collection immediately after final field measurements have been recorded. Refer to sections 4.2.1 and 4.2.2 for guidelines relevant to water-supply wells and monitoring wells, respectively.

- Do not stop the pump after purging, but record the rate of pumping.
- Pump samples from the well through the sample tubing that goes directly into the processing chamber.

If samples will be withdrawn using a thief-type sampler, lower and raise the sampler smoothly at a constant rate, keeping the suspension line clean and off the ground.

- **A bailer or other thief-type sampler is not recommended for trace-element or volatile organic compound (VOC) sampling.**
- Bailing can mobilize particulates and, unless designed for VOC sampling, can allow VOCs to escape. See section 4.2.2, Step 4, under "Nonpumped samples" (p. 88), for additional guidelines if a nonpumping sampling device will be used.

Field Cleaning of Sampling Equipment

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

4.2.1 WATER-SUPPLY WELLS

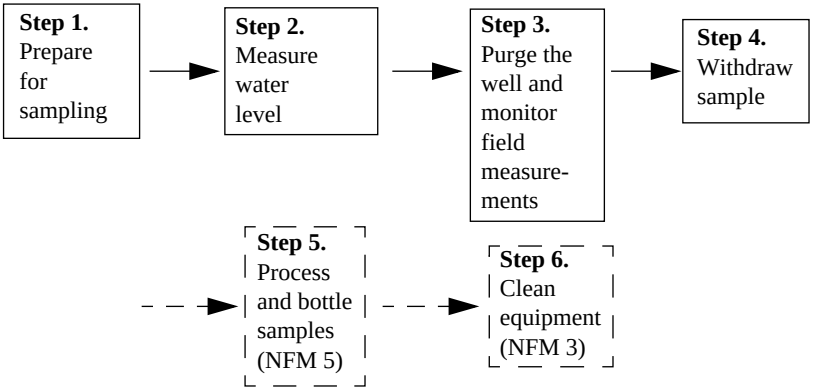
Collection of samples from water-supply wells with permanently installed pumps requires specific considerations, preparations, and precautions. Refer to other NFM chapters for guidelines for reconnaissance and preparations at supply-well sites (NFM 1) and safety precautions (NFM 9). Field personnel should be aware of the potential sources of contamination to samples withdrawn from supply wells (table 4-5; NFM 1).

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

Table 4-5. Advantages and disadvantages of collecting water samples from supply wells with permanently installed pumps

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

Protocols and guidelines for sampling from water-supply wells



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies. Implement good field practices and *CH/DH* techniques, as applicable (duties typically performed by Clean Hands (*CH*) and Dirty Hands (*DH*) are indicated in the steps that follow).

Step 1. Prepare for sampling at a supply-well site *(CH/DH)*.

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

   - Check the well identification number and compare it with the number in the well file and in field notes (NFM 1).
   - Assign *CH/DH* tasks.

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

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

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

d. Calibrate field-measurement instruments (*DH*). (Refer to NFM 6 for instructions.)

e. Spread clean plastic sheeting (for example, a polypropylene tarp) around the well to keep sampling equipment and sample tubing clean. Prepare area to be used for field cleaning of equipment (*DH*). Put on gloves.

f. Set up sample processing and preservation chambers in a clean workspace (usually in the water-quality field vehicle). Change gloves. Place filter unit and other necessary supplies for sample collection and processing into the processing chamber (*CH*).

g. Connect sample tubing as close to the wellhead as possible (*DH*).

   i. Determine the location and method of hookup to the well.

      - There must be no water-storage tanks, holding or pressurization tanks, or chemical disinfection or water-softening systems inline between the pump and tap or faucet to which sample tubing will be attached. Obtain written permission to install a tap to bypass any holding tank or chemical treatment system.
      - Select a faucet without an aerator, or obtain written permission from the owner to remove the aerator.

   ii. Use connectors and sample tubing that are compatible with the target analytes and that will not contaminate the sample. Clean connectors and tubing before use. At highly contaminated sites, it is recommended that this equipment be dedicated to that site or disposable equipment be used. Because connector fittings compatible with existing plumbing can vary, check that you have the size and configuration needed, and carry various sizes as spares.

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

   iv. Connect an adequate length of sample tubing from the antibacksiphon valve to manifold; from manifold, connect lines to flowthrough chamber, to processing chamber, and to waste discharge. Keep the discharge end of the sample tubing sealed until use. Keep tubing for sample and field-measurement lines as short as possible and protected from direct sunlight and extreme temperatures.

      - Tubing that transfers sample to the processing chamber must be of noncontaminating material, such as fluorocarbon polymer, and handled by *CH*.

- Tubing connected to a flowthrough chamber for field measurements that is used for that purpose only (not for sample collection) can be of any material, but should be transparent in order to see if bubbles or sediment are entrained in the sample flow (*DH*).
- Tubing that is used solely to discharge purged water or other wastewater can be of any material, but needs to be long enough to direct water away from the work area (*DH*).

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

Procedures and equipment for water-level measurement depend on well type and construction and the presence of nonaqueous liquid phases.

a. Put on gloves if chalking a steel tape. Using a weighted steel or electric tape in a nonpumping well, measure water level to the nearest 0.01 ft (for wells < 200 ft to water); repeat measurement until precision is within 0.02 ft. At deep wells, calculate the compensation factor to account for tape stretching.
   - Care must be taken not to entangle the well tape in the pump discharge pipe or intake.
   - An unweighted tape might be necessary if the weight cannot fit past the pump apparatus.
   - At some supply wells, the water level can only be estimated using the less accurate air-line method.

b. Record water-level measurements on field forms (fig. 4-7) and note any deviations from standard water-level measuring procedures.

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

A supply well that is in regular service and that is pumping continuously or that has been operating long enough to have removed three casing volumes of water within several hours of sample collection does not require removal of three well volumes. Sample tubing needs to be flushed with sample and the field measurements monitored before sampling, however. It is recommended that water level in the well should be maintained above the screened or open interval to ensure a representative sample.

- Adjust the flow rate at the pump (preferable) or use a manifold with a flow-regulating valve (needle valve), if possible. The flow-regulating valve is necessary to prevent backpressure and air bubbles from building in the line. **Flow should not be halted or the flow rate changed suddenly during the final phases of purging and sampling.**
- The pump should produce a smooth, solid stream of water without air or gas bubbles and without pump cavitation during field measurements and sample withdrawal.
- **Contain and dispose of purge water as required by Federal, State, or local regulations.** Do not discharge the purge water from one well into another without proper authorization. Discharge the water far enough away from a well or well cluster so as not to affect water quality in the well.

a. Calculate the well volume: **V**olume, in gallons = **(0.0408)** x (**H**eight of water column) x (inside **D**iameter^2 of well, in inches). Note that depth to bottom of well and inside casing diameter must be known to calculate well volume. Begin to calculate the three well volumes after discharging the initial volume of water to waste until sediment is cleared from the flow. Record the start and end times of purging, the purging rate, water levels, and location of pump intake (fig. 4-7).

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

b. Open any additional valves or taps/faucets to ensure that the pump will operate continuously and to reduce the possibility of backflow of water stored in ancillary plumbing lines. Keep all principal discharge lines (faucets and tap) open during sample collection that are open during purging. **Flow must not be interrupted during purging, field measurements, or sample collection.**

c. Begin flow through the flowthrough chamber for field measurements. Adjust flow to the chamber (NFM 6) from the pump, if possible, using a manifold with flow-regulating valves. **Do not use a flow-splitting valve to adjust flow rate.**

Once flow is constant, begin monitoring field measurements. (Instructions for monitoring field measurements are provided in NFM 6.)

- To control the flow rate from the manifold, a flow-regulating valve (such as a needle valve) is needed.
- Keep three-way valves either completely open or closed. Partially open three-way valves can create a vacuum and air bubbles and can draw in water that has possibly been in contact with contaminating materials. **Do not use a three-way valve or flow-splitting valve to regulate the flow.**

d. Calculate and record the final pumping rate. When water is flowing through more than one conduit (valve, tap/faucet, manifold lines) calculate the pumping rate by summing the rate of flow through each conduit. **The final pumping rate, used during the final five sets of field measurements, also should be used during sample collection**.

e. As the final well volume is removed, record on field forms at least five sets of field measurements at regularly spaced intervals and check data against stability criteria (fig. 4-7; NFM 6). Recommended measurements include specific electrical conductance, pH, temperature, dissolved oxygen, and turbidity.

Step 4. Withdraw sample (*CH*).

Flow should be constant and uninterrupted during purging and sampling. Regulate flow at the pump (as described below in Step 3).

a. Wearing gloves, check that the sample tubing is properly secured within the processing chamber.

b. Direct sample flow through sample tubing to processing chamber immediately after final field measurements have been recorded.

Step 5. Process sample ➜ Refer to NFM 5.

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

- **500 mL/min for bottles 250 mL or greater in volume, or**
- **150 mL/min for 40-mL VOC vials.**

Step 6. Clean equipment ➜ Refer to NFM 3.

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

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

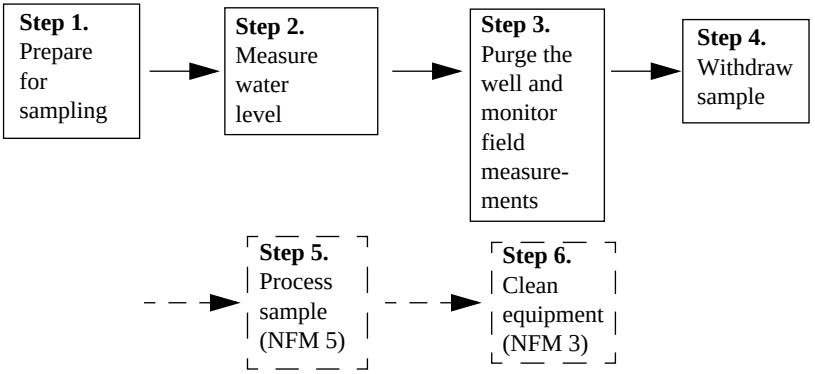
4.2.2 MONITORING WELLS

Ground-water samples commonly are collected from monitoring wells using portable sampling equipment. Sampling equipment can be dedicated for use at a specific well or can be installed permanently for the duration of the study, if using the same equipment for several wells poses a substantial risk of cross contamination.

Check NFM 2 for applications and limitations of various purging and sampling devices (pumps, bailers, and other samplers). Submersible pumps are recommended in general, but site characteristics can place limitations on the practical use of various types of sampling equipment. **If possible, the pump that is used for sampling also should be used for purging.**

- Select equipment that will not alter the chemical composition of the sample with respect to target analytes. Use only clean equipment.
- Several months in advance of sampling, quality assure the sampling equipment selected with an equipment blank(s) to verify that the equipment is suitable for the purpose of the study.
- Obtain permission for access to and collection of samples and data from the well.
- Document all field observations and any deviations from standard sampling procedures.

Protocols and guidelines for sampling from monitoring wells



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies. Implement good field practices and *CH/DH* techniques as applicable (duties typically performed by Clean Hands (*CH)* and Dirty Hands (*DH*) are indicated in the steps that follow).

Step 1. Prepare for sampling at a monitoring-well site (*DH/CH*).

a. Set out safety equipment such as traffic cones and signs. Park vehicle in a position to prevent sample contamination from vehicle and traffic emissions and prevailing wind.

- Check well-identification number and compare it with the well file and field notes.
- Assign *CH/DH* tasks to field personnel.

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

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

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

d. Set up equipment and instruments for field measurements and sample withdrawal (*DH*).

- Keep sample tubing shaded from direct sunlight to minimize changes in the temperature of the sample.
- Calibrate field-measurement instruments (NFM 6).

e. Spread clean plastic sheeting (for example, a polypropylene tarp) on the ground around the well to keep sampling equipment and sample tubing clean (*DH*). Prepare area to be used for field cleaning of equipment. Put on gloves.

f. Set up sample processing and preservation chambers (usually in the water-quality field vehicle). Change gloves. Place filter unit and other necessary supplies for sample collection and processing into the processing chamber (*CH*).

g. Remove cap from well casing and connect manifold to pump (if using a pump) (*DH*). Verify clear access downhole by lowering a section of blank pipe through the depth interval to be sampled and raising it slowly. **Do not drop the pipe or otherwise stir up particulates in the process of lowering and raising the pipe.**

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

ii. Connect sample tubing to manifold, keeping tubing as short as possible.

iii. From manifold, connect lines to flowthrough chamber, processing chamber, and waste discharge. Keep the discharge end of sample tubing (handled by *CH)* sealed until used. Keep tubing for sample and field-measurement lines as short as possible and protected from direct sunlight and extreme temperatures.

- Tubing that transfers sample to the processing chamber must be of noncontaminating material (*CH*).
- Tubing connected to a flowthrough chamber for field measurements that is used for that purpose only (not for sampling) can be of any material, but should be transparent in order to see if bubbles or sediment are entrained in the flow (*DH*).
- Tubing connected to the manifold that is used solely to discharge purge water or other wastewater can be of any material, but it needs to be long enough to direct water away from the work area (*DH*).

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

Procedures and equipment for water-level measurement depend on well type and construction and the presence of nonaqueous liquid phases.

a. Put on gloves before chalking a steel tape. Using a weighted steel or electric tape in a nonpumping well, record two or more consecutive water-level measurements to the nearest 0.01 ft (for wells of less than 200 ft to water); repeat measurement until precision is within 0.02 ft (U.S. Geological Survey, 1980). At deep wells, calculate the compensation factor to account for tape stretching.

b. Record water-level measurements on field forms (fig. 4-7).

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

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

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

Purge wells with a pump, if possible. Operate pumps in a manner that minimizes turbidity. **Do not use a bailer for purging** unless well characteristics or other constraints exclude other alternatives and the turbidity during and after bailing is less than about 5 NTU or at background level. Measuring water levels is recommended throughout purging to document drawdown and the location of the water level with respect to the screened/open interval and the pump intake.

- Use the same pump equipment for purging that will be used to collect samples, if possible.
- **Avoid refueling or changing equipment, and do not stop the pump during the final phase of purging and sample collection.** Be aware of study objectives and potential sources of contamination. For example, avoid fueling the equipment on the same day that samples are collected for VOC analysis.

- Adjust the flow rate at the pump (preferable) or use a manifold with a flow-regulating valve (needle valve). The flow-regulating valve is necessary to prevent backpressure and air bubbles from building in the tubing.
  - **Pump at a rate that does not significantly lower the water level. The water level should be maintained above the screened or open interval.**
  - **Flow should not be halted or the flow rate changed suddenly during the final phases of purging and sampling.**

TECHNICAL NOTES:

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

a. Calculate and record well volume (figs. 4-6 and 4-7) using the static depth to water measured in Step 2, as follows:

$V=0.0408HD^2$ [**V**olume, in gallons = (0.0408) x (**H**eight of water column, measured in feet as well depth minus water level) x (inside **D**iameter^2 of the well, in inches)]. Note that depth to bottom of well and inside casing diameter must be known to calculate well volume.

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

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

c. Position the pump intake.

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

d. Start the pump, channeling initial discharge to waste.

- Gradually increase and (or) adjust the pumping rate to limit drawdown to between 0.5 and 1 ft (≈0.15 to ≈0.3 m). Control the flow rate through the field-measurement tubing from the pump, if possible; or use a flow-regulating valve on the manifold. **Do not use a flow-splitting valve to adjust flow rate.**
- Record changes in water level during purging.
- Do not halt or suddenly change the flow rate during the purging/sample collection process. The pump must produce a solid stream of water during field measurements or sample collection. Adjust the pumping rate to eliminate air or gas bubbles or pump cavitation.

e. Do not move the pump during field measurements or sample collection after intake has been set at the final location. **The final depth of pump intake must be the same for making field measurements as for sample collection.**

f. **Discharge water to waste until sediment is cleared from the flow.** Begin flow through the flowthrough chamber for field measurements. Regulate the flow to the flowthrough chamber, as required, for measurements of pH and dissolved oxygen (NFM 6).

g. Record the start time of purging, the pumping rate(s), water levels, and final location of pump intake (fig. 4-7). If water is flowing through more than one conduit (such as valve and manifold lines), calculate flow rate by summing the flow rate through each conduit.

h. Purge a minimum of three well volumes or the purge volume dictated by study objectives. (Check exceptions to the three-well-volume procedure described on p. 69.)

- Record water-level and field measurements and time of measurement throughout purging (fig. 4-7; NFM 6).
- **The final pumping rate toward the end of purging (when stability of five or more sets of field measurements are being monitored) must be the same as the pumping rate during sample collection**.
- Check for special instructions regarding any field-measurement or field-analysis requirements based on study objectives.
- **Contain and dispose of purge water as required by Federal, State, or local regulations.** Do not discharge purge water from one well into another without proper authorization. Discharge the water far enough away from a well or well cluster so as not to affect water quality.

i. Check field-measurement data against stability criteria (fig. 4-7), as instructed in NFM 6. Record the time purging ended and note any deviations from standard well-purging procedures.

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

Put on gloves and begin sample collection immediately after field measurements have been completed.

Pumped samples—

a. Check that sample tubing is properly secured within the processing chamber. Direct the sample flow through sample tubing to the processing chamber.

b. Use the flow-regulating valve on the manifold to adjust sample flow to be smooth and uniform; avoid splashing while filling sample bottles.

c. Go to Step 5.

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

- **500 mL/min for bottles 250 mL or greater in volume, or**
- **150 mL/min for 40-mL VOC vials.**

Nonpumped samples—

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

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

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

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

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

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

   vi. Repeat rinse procedure at least twice.

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

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

c. Composite the bailed sample or set up bailer in an enclosed or protected space.

Step 5. Process sample ➜ Refer to NFM 5.

Step 6. Clean equipment ➜ Refer to NFM 3.

At contaminated sites, use sample tubing that is disposable or dedicated to that site to avoid lengthy field-cleaning procedures and to minimize the risk of cross-contamination between wells.

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

QUALITY-CONTROL SAMPLES 4.3

By F.D. Wilde, T.L. Schertz, and D.B. Radtke

Collection of quality-control (QC) samples is a required component of sample collection for water-quality studies. QC samples are collected, usually at the field site, in order to identify, quantify, and document bias and variability in data resulting from the collection, processing, shipping, and handling of samples by field and laboratory personnel. **The bias and variability associated with data must be known so that environmental data can be adequately interpreted** (Horowitz and others, 1994; Koterba and others, 1994; Koterba and others, 1995).

The procedures for collecting QC samples can depend on, or be modified according to, the purpose of the quality-assurance program. Thus, personnel need to understand the purpose for each QC sample to be collected (Appendix A4-B) and how the resulting QC data will be used. The type, number, and distribution of QC samples are determined by the design and data-quality requirements of the study. For any water-quality sampling schedule, personnel must:

- **Be aware that an equipment blank is required at least annually (NFM 3).**
- **Be alert to field conditions** for which blanks or other QC samples should be collected, in addition to those planned. **It is usually best to collect the additional QC samples;** it can be decided later whether to submit them for laboratory analysis.
- **Collect all field QC samples on the same day that environmental samples are collected,** using the same equipment as for environmental samples.

- **Obtain the QC sample solutions needed.**
  - **Blanks.** The source solution needed for blank samples must be produced and certified by a laboratory to have analyte concentrations that do not exceed a specified method detection limit. Review and keep on file the certificate of analysis for each lot of blank water; keep a record of the lot numbers used for each sample.
    - **Inorganic-grade blank water (IBW)** is required for blanks that will be analyzed for inorganic constituents.
    - **Pesticide-grade blank water** (**PBW**) **and volatile-grade blank water** (**VBW**) are required for blanks that will be analyzed for pesticides and volatile organic compounds, respectively. VBW can also be used for pesticide blanks.
    - **VOC trip blanks** must be requested from the laboratory as a separate order and can be shipped with an order for VOC vials.
  - **Replicates and field-matrix spikes.** The surface or ground water being sampled (environmental water) is the solution used for most types of replicates (sequential, split, and concurrent samples) and spikes.
  - **Standards and reference materials.** Standards and reference materials are either artificial or environmental solutions with known and certified analyte concentrations.
    - Reference materials usually are obtained from the National Institute of Standards and Technology (NIST) (http://www.nist.gov).
    - USGS personnel can obtain Standard Reference Water Samples (SRS) from the USGS Branch of Quality Systems (http://btdqs.usgs.gov).
- **Use preservatives from the same lot number** for the environmental and associated QC samples. Record preservative lot number.

- **Label QC sample bottles** with a QA sample-designation code, site identification number, date of sample collection, and an assigned or real time of collection. Identification of specific types of QC samples can follow a study-developed time-coding protocol in which a specific time interval is assigned that pertains only to a specific type of QC sample.
- **Store QC data in an electronic data base devoted to QC data.** For USGS studies, it is recommended that this be an alternative data base within NWIS QWDATA—check for District and (or) program protocols for QC data-storage requirements.

Use Good Field Practices (table 4-1) and Clean Hands/Dirty Hands techniques (table 4-2) when collecting and processing QC samples.

BLANK SAMPLES 4.3.1

The primary purpose of a blank sample is to identify potential sources of sample contamination and assess the magnitude of contamination with respect to concentration of target analytes (Appendix A4-B). There are many possible types of blanks, and the processing procedures described below and in Appendix A4-B address only those most commonly collected. (Additional information can be found in Branch of Quality Systems memorandums 92.01 and 95.01; Sandstrom, 1990; Horowitz and others, 1994; and Koterba and others, 1995, although terminology differs somewhat among these references.) Examples to estimate the volume of blank solutions needed for field QC and blank-collection protocols are given in Appendix A4-C.

4.3.1.A Source-Solution, Equipment, Trip, and Other Prefield Blanks

Prepare the source-solution blank, equipment blank, and trip blank before going to the field for environmental sampling. Wear gloves and conform to other clean-hands practices when working with blank solutions.

- **Source-solution blank.** Collect in a designated clean, draft-free area of the office laboratory, such as under a laminar-flow hood or laminar-flow bench. **Do not collect the source-solution blank in a fume hood.** Submit the sample for analysis along with field-collected samples.
- **Equipment blank.** Collect in a designated clean area of the office laboratory. Collect the equipment blank at least 4 weeks before using the equipment in the field to ensure enough time for chemical analysis and review of the resulting QC data.
- **Trip blank**. Carry the trip blank as received from the laboratory to the field site. Do not open, but store with the environmental samples collected for the same target analytes, and submit for analysis along with the field-collected samples. Record the trip-blank lot number on the NWQL Analytical Services Request (ASR) form submitted with the vial. (The lot number can be found on the box, and is sometimes printed on the label.)

A variety of other types of blank samples that are collected in the controlled office-laboratory environment can be designed to test some aspect of sample handling not related to field activities. Examples of this type of blank (described in Appendix A4-B) include the refrigerator blank, the shelf blank, and the preservation blank.

When working with blank water, wear disposable, powderless gloves and implement clean-sampling techniques.

Ambient and Field Blanks 4.3.1.B

The collection of blank samples, described in this section, addresses onsite (field) processing of blank water in the same environment in which the surface- or ground-water samples are collected and (or) processed.

To prepare for processing blank samples:

1. Label the capped, precleaned sample bottle with the site identification number, laboratory sample designation code (NFM 5), date, and time.
2. Put on gloves. Place each stock container of the blank solution to be used into clean plastic bags.
   - IBW—Required for trace-element, major-ion, and nutrient field-blank analysis.
   - PBW—Required for pesticide field-blank analysis; can be used as a blank for total or dissolved organic carbon (TOC/DOC).
   - VBW—Required for VOC field-blank analysis; can be used as a blank for TOC/DOC and pesticides.
3. If pumping blank water from a standpipe, change gloves and then rinse the precleaned standpipe three times using a small volume of blank solution of the type selected. Keep standpipe covered until use.
4. Change gloves. Place precleaned, labeled sample bottle(s) and the stock of blank solutions to be used into processing chamber.
   - IBW blanks—Discard the deionized water that half fills the precleaned polyethylene sample bottle. Rinse the sample bottle with a small quantity of blank solution and discard rinsate before filling with IBW.
   - PBW or VBW blanks—Do not prerinse the sample bottle. Use glass bottles or vials as received precleaned from the laboratory.

Ambient blanks

Ambient blanks are used to answer questions such as "To what extent could exposure of the sample to its collection and processing environment introduce measurable concentrations of target analytes?" Depending on the site characteristics or conditions being subjected to quality control, different procedures can be used for collecting the ambient blank. Three common procedures are described below. For each procedure, prevent contamination of the source solution and blank sample by capping the respective bottles immediately after use.

Procedure 1. Fill clean sample bottle(s) with the appropriate blank water in the same office-laboratory area in which the source-solution blank is collected, and transport to the field. Place the bottle(s) in the processing or preservation chamber or other area in which the environmental sample(s) are being processed. Open the blank-sample bottle to expose blank sample to the chamber atmosphere for the period of time in which the environmental sample(s) are being processed. Cap the bottle(s) and label appropriately.

Procedure 2. Working within the area being tested (usually the area in which the environmental sample is being collected or processed), pour blank water from the source-solution container directly into the sample bottle. Cap the bottle immediately and label appropriately. The goal is to use similar procedures to expose an identical volume of blank water to the ambient atmospheric conditions as that for collection of sample water.

Procedure 3. While working within the area being tested (such as a field vehicle), fill a clean, wide-mouthed container with the type of blank water desired and leave open to the atmosphere for the entire testing period. Pour the blank water into a clean sample bottle. Cap the bottle and label appropriately. (This type of ambient blank is sometimes referred to as an atmospheric blank.)

Field blanks

Field blanks are collected and processed at the field site in the same manner and using the same equipment as the environmental sample(s). Equipment must be meticulously cleaned for collection of field blanks (NFM 3). Field blanks answer questions such as "Has this component of the equipment system been adequately cleaned?" or "Does this equipment component introduce detectable concentrations of target analytes?" or "Is there carry-over contamination from the previous sampling site?"

- Field blanks can represent equipment components of the sampling system; for example, the sampler blank, splitter blank, filter blank, or pump blank. (The pump blank for ground water often is the same as or analogous to a sampler blank, when a pump is the type of sampler used to withdraw water from its original source.)
- A single field blank that represents the entire sampling system is commonly referred to as the field blank or field-system blank (fig. 4-8 and Appendix A4-B). The field blank is comprised of an aliquot of blank water processed sequentially through each component of the sampling system.

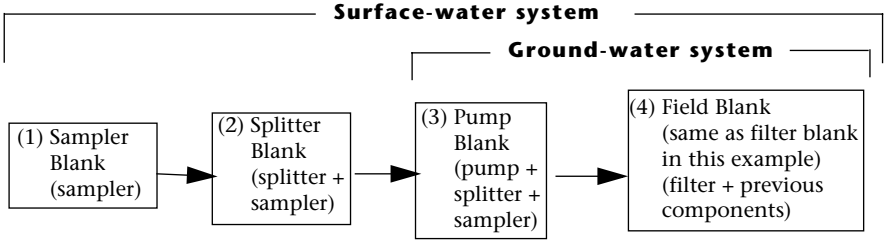
Submit field blanks for laboratory analysis of the same target analytes as the environmental sample(s). If the analytes being quality controlled are inorganic, preserved with acid, and are not time dependent, the sequential blank samples representing components of the sampling system and any associated source-solution and ambient blanks normally can be stored for up to 6 months.

1. If the field-blank data indicate constituent concentrations at acceptable levels, the associated set of sequential blanks can be discarded. (Be sure to use appropriate means for disposing of chemically treated solutions.)
2. If laboratory data indicate greater than acceptable concentrations:
   a. Submit the source-solution blank, ambient blank(s), and equipment-component blank(s) (the sampler blank, splitter blank, pump blank, and so forth) to the laboratory for analysis.
   b. Use the data from equipment-component blank samples to identify the source(s) of contamination detected in the field blank.
   c. **Take appropriate measures to eliminate contamination during future sampling trips.**

EXAMPLE PROCEDURE FOR COLLECTING FIELD BLANKS

A set of blanks can be generated that is associated with the field blank to help determine which equipment component in the system could be a source of contamination. The **field blank** is the final sample that represents all equipment components of the sampling system. After each blank sample is collected, preserve and store sample as required.

- **Follow steps 1 through 4 to process a surface-water field blank.** In this example, the equipment used includes a US D-77 sampler, 8-liter (L) churn splitter, peristaltic pump, and filter assembly.
- **Follow steps 3 and 4 to process a ground-water field blank.** In this example, the equipment used includes a submersible pump and a filter assembly.



(1) Sampler Blank. Using the blank water selected, rinse and then fill the sampler; attach sampler cap and nozzle; pour the required volume through nozzle into sample bottle.

(2) Splitter Blank.[1] Rinse churn splitter with blank water. Pour the blank water remaining in the sampler through the sampler nozzle and into the 8-L churn splitter. Refill sampler, repeat until churn contains 3 to 5 L of blank water. Process the required blank-sample volume through the churn spigot into the splitter-blank bottle. (If a cone splitter is used instead of a churn splitter, the blank sample is processed through the exit port tubes.)

(3) Pump Blank.[1]

- **Surface-water example**: Using the peristaltic pump, thread the intake end of clean tubing into churn splitter through the funnel, and cap the funnel loosely. Insert the discharge end of the pump tubing into a processing chamber and pump blank water through the tubing for an initial rinse, discharging rinse water to waste. After the rinse, pump the required volume of blank water from the churn splitter into the pump-blank bottle.
- **Ground-water example:** Rinse a precleaned, noncontaminating standpipe with blank water and discard rinse water. Place submersible pump into the standpipe and pour in blank water—keep water level above the pump intake. Insert discharge end of pump tubing into a processing chamber. Circulate blank water through pump and tubing to rinse, discharging rinse water to waste. Pump the required volume of blank water from the standpipe into the pump-blank bottle.

(4) Field-System Blank (the field blank). The **field blank** in this example is the same as a special type of **filter blank**[1] because the filter assembly is the final component of the equipment system through which the blank is processed. Working in the processing chamber, precondition the filter with blank water (NFM 5).

- **Surface-water example:** Pump the required volume of blank water from the churn splitter through the prerinsed filter assembly into the field-blank bottle.
- **Ground-water example:** Pump the required volume of blank water from the standpipe through the prerinsed filter assembly into the field-blank bottle.

[1]These are special cases of a splitter blank, pump blank, and filter blank, respectively, because the equipment component named is the final component but not the only component contacting the blank sample.

Figure 4-8. Example of procedure for collecting field blanks and associated blank samples.

REPLICATE SAMPLES 4.3.2

The primary purpose of replicate samples is to identify and (or) quantify the variability in all or part of the sampling and analysis system. Replicates—environmental samples collected in duplicate, triplicate, or higher multiples—are considered identical in composition and are analyzed for the same chemical properties. Common types of replicates are described below.

Concurrent Replicate Samples 4.3.2.A

Concurrent replicates are simultaneously collected samples of environmental water used to answer questions such as "What was the variability introduced from collection, processing, shipping, and laboratory handling of the sample?" Concurrent replicates can be designed to assess variability inherent in the system being sampled (Appendix A4-B).

Depending on study objectives, concurrent samples can be collected by using two sampling devices of the same type simultaneously or by filling separate sample-compositing containers concurrently using the same sampling device. The following procedure (from Horowitz and others, 1994) is used at surface-water sites to fill two or more sample-compositing containers (usually churn splitters) and incorporates Clean Hands/Dirty Hands techniques:

1. Complete equipment field-rinsing procedures (section 4.0.2). Label bottles appropriately. Change gloves.
2. At the first vertical of an EWI or EDI section, collect a sample and pour into a field-rinsed churn splitter (section 4.1).
3. Resample the first vertical and pour into the second churn splitter.
4. Move to second vertical, collect sample, and pour into second churn splitter.
5. Resample second vertical and pour into first churn splitter.
6. Collect and pour sample into each churn splitter in this manner for each of the remaining verticals, alternating churn splitters as described in 2-5 listed above.
7. Process and preserve a sample (a) from the first churn, and (b) from the second churn.

4.3.2.B Sequential Replicate Samples

Sequential replicates are samples of environmental water that are collected consecutively instead of simultaneously. Sequential replicates are used to assess variability among samples resulting from collection, processing, shipping, and laboratory procedures conducted at different sampling times. The sequential replicate can be designed to assess sample variability from inhomogeneities in the system being sampled by spacing samples over short or long time periods.

4.3.2.C Split Replicate Samples

Split replicates are samples that are divided into two or more equal subsamples, each of which is submitted to one or more laboratories for the identical analysis. Field-split samples are used to assess variability from sample processing and preservation. Bottles must be appropriately labeled, and the sequence of procedures used must be recorded.

To split a sample into two subsamples after the original has been processed and preserved, use the following procedure (from Horowitz and others, 1994):

1. Wearing disposable, powderless gloves and working inside a processing chamber, start with a full sample bottle of processed (whole-water or filtered) sample.
   - For inorganic samples only, use a bottle rinsed twice with deionized water and then field rinsed with a small volume of processed sample.
   - Do not field rinse bottles for organic samples.
2. Transfer entire contents of first bottle to second bottle, cap second bottle, and thoroughly shake bottle to mix.
3. Pour entire contents of second bottle back into first bottle.
4. Pour one-half of sample from first bottle back into second bottle, then cap both bottles.

To split concurrent replicate samples that were processed through separate compositing devices (such as churn splitters), follow the procedure listed in 1-4 above and label the samples as follows (from Horowitz and others, 1994):

Churn splitter #1: first bottle "Site (X), Sample 1, Split A"
"Site (X), Sample 1, Split B"

Churn splitter #2: first bottle "Site (X), Sample 2, Split A"
"Site (X), Sample 2, Split B"

SPIKE SAMPLES 4.3.3

Spike samples are used to answer questions such as "What loss or gain of target analytes occurred because of water-matrix characteristics; the field processing, shipping, or handling procedures used; holding time; or laboratory analytical procedures?"

Typically, spikes are applied to samples to be analyzed for concentrations of organic compounds. A sample is spiked by adding a mixture of target compounds obtained from the laboratory to an environmental sample after the sample has been processed. **An unspiked environmental sample must accompany each spiked sample.**

Training is required before personnel attempt to spike samples. The spike kits provided to USGS personnel by the NWQL include the spike solution, equipment, and bottle labels, and detailed instructions.

The numbers and types of matrix spikes used depend on the objectives and data-quality requirements of individual studies, as determined by the project chiefs. Although analyses for a set of spike samples—laboratory spike, field spike, and field-spike replicate—provides the most complete information relating to the performance of the analytical method, the data from only laboratory spikes, or perhaps only one field spike, could be sufficient to meet study needs.

When preparing field-spiked samples for pesticides or VOCs, follow the procedure listed below:

1. Keep samples chilled until spiking. Label bottles appropriately.
2. Wearing gloves, spike each of the QC samples with the appropriate volume of the correct NWQL-provided spike solution:
   - Check that the pesticide samples are being spiked with pesticide-spike solution.
   - Check that the VOC samples are being spiked with VOC-spike solution.
3. Chill field-spiked samples to 4 °C or below without freezing, and handle in a manner identical to that of the environmental sample.
4. Record the following information related to the spike sample on field and NWQL Analytical Services Request forms:

   Lot number of spike solution, volume of spike solution, and source of spike solution.

4.3.4 REFERENCE SAMPLES

Standard-reference-water samples (SRS) and reference-material samples are used to answer questions, such as "What are the bias and variability associated with field-handling, shipping, and laboratory procedures?" Reference samples commonly are submitted from the field as blind samples (section 4.3.5) and as split replicate samples (section 4.3.2.C) because the composition is known, eliminating guesswork regarding the accuracy and correctness of the analytical results.

Reference samples with a natural water matrix are currently available to USGS personnel from the USGS Branch of Quality Systems. NIST and some commercial laboratories also supply reference materials.

When preparing reference samples, follow the procedure listed below:

1. **Prepare this sample before leaving for the field site.**
   a. Relabel the reference-sample bottle with the site identification code and a field date and time. The sample should appear as if it is an environmental sample.
   b. Process SRS or reference-material samples in a clean environment in the office laboratory, under a laminar-flow hood or other protective chamber, to avoid atmospheric contamination. **Do not process these QC samples under a fume hood.**
   c. Rinse each sample bottle three times with a small volume of SRS or reference-material sample, fill the bottle with the reference solution, and cap securely.
2. Prepare an ASR form; record the SRS or reference-material sample identification code (from the original container) in field notes.
3. Pack the sample and the accompanying ASR form to take to the field site.
4. Ship SRS or reference-material samples in the same container with the environmental and other QC samples collected at the field site.

BLIND SAMPLES 4.3.5

The source and chemical composition of blind samples are known to the submitter although typically not known to the analyst; therefore, blanks, SRS, or reference material usually are used as blind samples. Blind samples can be designed to answer questions such as "What bias and variability are introduced by procedures used within a single laboratory or among laboratories?" Replicate or spike samples also can be used to answer a similar question.

CONVERSION FACTORS, SELECTED TERMS, AND ABBREVIATIONS

CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
inch (in.)	25.4	millimeter
meter (m)	3.281	foot
micrometer (µm)	3.281×10^{-6}	foot
millimeter (mm)	0.03937	inch
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois
liter (L)	0.2642	gallon
milliliter (mL)	2.64×10^{-4}	gallon

Temperature: Water and air temperature are given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = 1.8(°C) + 32$$

SELECTED TERMS

Accuracy: The degree of agreement of a measured value with the true or expected value of the quantity of concern (Taylor, 1987).

Analyte (target analyte): "Substances being determined in an analysis" (from Bennett, 1986). The term target analyte is used in this report to refer to any chemical or biological substance for which concentrations in a sample will be determined. Target analyte does not include field-measured parameters such as specific electrical conductance, pH, temperature, dissolved oxygen, Eh, alkalinity, color, or turbidity.

Aquifer: "A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients" (Freeze and Cherry, 1979).

Area-weighted sample: A sample that contains an equal volume from each unit of area sampled.

Bias: Systematic error inherent in a method or caused by some artifact or idiosyncrasy of the measurement system. The error can be positive (indicating contamination) or negative (indicating loss of analyte concentration) (from Taylor, 1987).

Bag samplers: Samplers whose containers are bags that instantly transmit the ambient pressure to the interior of the sample container and do not have opening or closing valves.

Bottle samplers: A rigid sample container that does not instantly transmit the ambient pressure to the interior of the sample container and has neither pressure compensation nor opening and closing valves. Point samplers described in Edwards and Glysson (1998) use rigid bottles but have pressure compensation and opening and closing valves and are not considered bottle samplers for the purposes of this document. **The tables in Appendix A4-A were not designed for use with point samplers.**

Centroid (as used to designate a special case of stream-sampling location for the equal-discharge-increment method)**:** The vertical in the increment at which discharge is equal on both sides of the vertical (G. Douglas Glysson, U.S. Geological Survey, written commun., 1997).

Contaminant: Biological, chemical, or physical substances or properties added to the medium of concern through human activity or natural processes and that corrupt its ambient composition.

Contamination (of water): Corruption of ambient water composition or attributes by the addition of biological, chemical, or physical substances as a result of human activity or natural processes. Addition of such substances can degrade the quality of the water resource.

Data-quality requirements: That subset of data-quality objectives pertaining specifically to the analytical detection level for concentrations of target analytes and the variability allowable without compromising achievement of the scientific objectives of the study.

Depth-integrated sample: A sample collected when each vertical portion of the stream depth is represented in the sample in proportion to the desired sampling scheme.

- **Depth integration.** "A method of sampling at every point throughout a given depth (the sampled depth) whereby the water-sediment mixture is collected isokinetically so that the contribution from each point is proportional to the stream velocity at the point. This process yields a sample with properties that are discharge weighted over the sampled depth" (ASTM, 1990).

- **Depth integration for a discharge-weighted sample.** "A discharge-weighted (velocity-weighted) sample of water-sediment mixture collected at one or more verticals in accordance with the technique of depth integration; the discharge of any property of the sample expressible as a concentration can be obtained as the product of the concentration and the water discharge represented by the sample" (ASTM, 1990). For a discharge-weighted sample, the water-sediment mixture is collected isokinetically so that the contribution from each point is proportional to the stream velocity at the point (that is, the sample contains an equal volume from each unit of discharge sampled).

- **Depth integration to collect an area-weighted sample.** The ASTM definition of depth integration does not accommodate the concept of an area-weighted sample. Area weighting is similar in concept to discharge weighting, except that the water-sediment mixture is collected so that the contribution from each point is proportional to the stream area at the point (that is, contains an equal volume from each unit of area sampled). Area-weighted sampling is used to obtain a sample that contains the average concentration of a property that is observed in a cross section. Averaged in situ field measurements of streams are more nearly area weighted than discharge weighted. The product of an area-weighted property concentration and the stream discharge would not yield the discharge of the property unless the stream contained the same property concentration at every point.

Discharge-weighted sample: A sample that contains an equal volume from each unit of discharge sampled.

District: An office of the USGS, Water Resources Division, located in any of the States or territories of the United States.

Equal-width-increment (EWI) and **equal-discharge-increment (EDI) sample-collection methods:** Methods specifically designed to result in the collection of discharge-weighted, depth-integrated, isokinetic samples (Edwards and Glysson, 1998). When either method is used properly, the resulting samples contain the same property concentrations.

Isokinetic sampling: A sample collected in such a way that the water-sediment mixture moves with no change in velocity as it leaves the ambient flow and enters the sampler intake (ASTM, 1990).

Precision: The degree of mutual agreement characteristic of independent measurements as the result of repeated application of the process under specified conditions (Taylor, 1987).

Quality Assessment: Overall process of assessing the quality of the environmental data by reviewing the application of the quality-assurance elements and the analysis of the quality-control data.

Quality Assurance (QA): A system of protocols and procedures implemented to meet expected standards of quality needed to fulfill study objectives and control unmeasurable components of a study, such as sampling at the right place and (or) time using the correct equipment and techniques.

Quality Control (QC): A system of activities (such as collection of blank or replicate samples) whose purpose is to assess the quality of environmental data by generating a set of data that will be used to estimate the magnitude of the bias and variability resulting from the procedures used for obtaining the data.

Raw sample: A whole-water (unfiltered) sample that has not been processed through a filter or other phase-separation device.

Transit: To move the sampler from the stream surface to the streambed or from the streambed to the surface.

Transit rate: The rate at which the sampler is passed through the water from the stream surface to the streambed or from the streambed to the surface.

Unsampled zone: The unsampled portion of the sampling vertical, usually assumed to be the zone from the streambed to the sampler intake. Generally, sampler intakes are 4 to 7 inches above the streambed, depending on the kind of sampler used.

Variability: Random error in independent measurements as the result of repeated application of the process under specific conditions.

Vertical: Refers to that location within the increment at which the sampler is lowered and raised through the water column.

ABBREVIATIONS

<	less than
≤	equal to or less than
≥	equal to or greater than
ft/s	feet per second
gal/min	gallon per minute
L/min	liter per minute
µg/L	microgram per liter (equivalent to parts per billion)
mg/L	milligram per liter
mL/min	milliliter per minute
ppb	parts per billion (equivalent to micrograms per liter)
ASR	Analytical Services Request
ASTM	American Society for Testing and Materials
CFC	chlorofluorocarbon
CH/DH	Clean Hands/Dirty Hands
DIW	distilled, deionized water
DOC	dissolved organic carbon
EDI	equal-discharge increment
EWI	equal-width increment
FTU	Formazin turbidity unit
IBW	inorganic-grade blank water
ID	identification number that is unique to a field site, station, or well
NAWQA	National Water-Quality Assessment Program
NFM	*National Field Manual for the Collection of Water-Quality Data*
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric turbidity unit
NWQL	National Water Quality Laboratory
PBW	pesticide-grade blank water
PCB	polychlorinated biphenyls
QA	quality assurance
QC	quality control
QWSU	Quality Water Service Unit
SRS	Standard reference water sample
TBY	turbidity
TOC	total organic carbon
URL	Uniform Resource Location
USGS	U.S. Geological Survey
VBW	volatiles-grade blank water (is also of pesticide grade)
VCF	single vertical at centroid of flow
VOC	volatile organic compound

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Internal Documents

The following Branch of Quality Systems (formerly Branch of Quality Assurance), Office of Water Quality, and National Water Quality Laboratory technical memorandums are available on the World Wide Web at http://water.usgs.gov/lookup/get?techmemo.

Memo No.	Title	Date
	Branch of Quality Systems	
92.01	ADP—Storage of water-quality, quality assurance data in NWIS	February 5, 1990
95.01	ADP—Storage of water-quality quality assurance data in NWIS	October 28, 1994

Memo No.	Title	Date
	Water Quality	
qw92.02	FIELD TECHNIQUES—Field preparation of containers for aqueous samples	December 20, 1991
qw94.16	New preservation techniques for nutrient samples	August 5, 1994
qw95.02	Establishment of U.S. Geological Survey (USGS) Laboratory for determination of chlorofluorocarbons (CFCs) in air and water samples (joint office memo—also available as Office of Ground Water Technical Memorandum 95.02)	December 29, 1994
qw97.03	Protocols for cleaning a Teflon cone splitter to produce contaminant-free subsamples for subsequent determinations of trace elements	February 7, 1997
qw97.06	Comparison of the suspended-sediment splitting capabilities of the churn and cone splitters	May 5, 1997
qw99.02	Guidance for collecting discharge-weighted samples in surface water using an isokinetic sampler	November 3, 1998

Memo No.	Title	Date
	National Water Quality Laboratory	
92.04	Bottles for tritium analyses	August 12, 1992
93.09	Radon. - Discontinuance of duplicate samples for radon-in-water	August 24, 1993
95.04	Shipping samples to the National Water Quality Laboratory	December 2, 1994
95.05	Nitrogen isotope sample preservation for water samples	March 8, 1995
96.05	Collection, processing, and analysis of carbon isotope samples	April 5, 1996
97.04	Tritium/helium dating of ground-water samples available through contract with Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York	April 7, 1997

Memo No.	Title	Date
	Water Resources	
94.008	LEGAL-Agreement forms 9-1482, 9-1482A, and 9-1483	February 18, 1994

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 by accessing the World Wide Web url: http://water.usgs.gov/lookup/get?TWRI.

Book 1. Collection of Water Data by Direct Measurement

Section D. Water Quality

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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

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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.

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Book 4. Hydrologic Analysis and Interpretation

Section A. Statistical Analysis

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