GENERAL INFORMATION AND GUIDELINES 6.0

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

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GENERAL INFORMATION AND GUIDELINES 6.0

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

This section summarizes information, guidelines, and minimum requirements that apply generally to field measurements for all studies of water quality and the collection of basic data. Other terms commonly used for field measurements are field parameters and field analyses. Guidelines applicable to the individual field measurements are described in detail in the respective sections of this chapter (NFM 6.1 through 6.7). Before proceeding with field work, check each field-measurement section for recommended methods and equipment, detailed descriptions of measurement and quality-control procedures, and guidelines for troubleshooting and data reporting.

FIELD MEASUREMENTS—determinations of physical or chemical properties that are measured onsite, as close as possible in time and space to the media being sampled.

6.0.1 RECORDS, FIELD INSTRUMENTS, AND QUALITY ASSURANCE

Field-measurement data and other field information must be recorded, either on paper or electronically, while in the field. “Reported” field measurements are defined as those data that are entered into the National Water Information System (NWIS) data base of the USGS (Hoopes, 2004) as well as data that are to be published but cannot be stored in NWIS. The conventions used for reporting field-measurement data are described at the end of each field-measurement section.

- Record field-measurement data, methods and equipment selected, and calibration information on field forms and in instrument log books.
  - Field forms include national or study-customized field forms and analytical services request forms; other forms and records (for example, chain-of-custody records) may be required for the study.
  - Instrument log books for each field instrument are required to document calibrations and maintenance.
- Electronic records are maintained for each uniquely identified sampling location (NFM 1.2 and 1.3, and see NOTE below.

Field personnel must be familiar with the instructions provided by equipment manufacturers. This manual provides only generic guidelines for equipment use and maintenance or focuses on a particular instrument or instruments that currently are in common use in the USGS; there is a large variety of available field instruments and field instruments are being continuously updated or replaced using newer technology. Field personnel are encouraged to contact equipment manufacturers for answers to technical questions. Refer questions regarding equipment and supplies obtained from the National Water Quality Laboratory (NWQL) in Denver, Colo., or the Hydrologic Instrumentation Facility (HIF) at Stennis Space Center, Miss., to the respective facility

NOTE:
NWIS, QWDATA: record field measurements and analyses, including non-automated ground-water water-level measurements.
NWIS, GWSI: record all final non-automated ground-water water-level measurements.
NWIS, ADAPS: record all automated, continuous water data.

Field measurements should represent, as closely as possible, the natural condition of the surface-water or ground-water system at the time of sampling. Field teams must determine if the instruments and method to be used will produce data of the type and quality required to fulfill study needs as well as USGS requirements. Experience and knowledge of field conditions often are indispensable for determining the most accurate field-measurement value. To ensure the quality of the data collected:

- Calibration is required at the field site for most instruments. **Make field measurements only with calibrated instruments.**
- Each field instrument must have a permanent log book for recording calibrations and repairs. Review the log book before leaving for the field.
- Test each instrument (meters and sensors) before leaving for the field. Practice your measurement technique if the instrument or measurement is new to you.
- Have backup instruments readily available and in good working condition.

Quality-assurance protocols are mandatory for every data-collection effort of the USGS, and include practicing good field procedures and implementing quality-control checks. Make field measurements in a manner that minimizes artifacts that can bias the result. Check field-measurement variability (precision) and bias (accuracy plus variability).

- **Requirement:** Use reference samples to document your ability to make an accurate field measurement. **Field personnel, including non-USGS employees that collect field-measurement data entered into the NWIS, are required to participate in the National Field Quality Assurance (NFQA) Program** (http://nfqa.cr.usgs.gov**,** accessed 5/5/05). Field teams also are encouraged to verify accuracy of their measurements at least quarterly against reference samples obtained through the local water-quality specialist or contact the NFQA Program.

RULE OF THUMB:

For measurements such as alkalinity made on subsamples, check precision in the field every tenth sample by repeating the measurement three times using separate sample aliquots from the same sample volume.

- **Standard procedure:** Before making field measurements, allow sensor to equilibrate to the temperature of the water being monitored. Before recording field measurements, allow the measurement readings to stabilize. **The criteria for stabilized field readings are defined operationally in table 6.0–1, for a set of three or more sequential measurements.** The natural variability inherent in surface water or ground water at the time of sampling generally falls within these stability criteria and reflects the accuracy that should be attainable with a calibrated instrument.
  - **For surface water:** Allow at least 60 seconds (or follow the manufacturer's guidelines) for sensors to equilibrate with sample water. Take instrument readings until the stabilization criteria in table 6.0–1 are met. Record the median of the final three or more readings as the value to be reported for that measurement point (see 6.0.2).
  - **For ground water:** Start recording measurements after sensors have equilibrated with purge water. Take instrument readings until the stabilization criteria in table 6.0–1 are met and the required number of well volumes of ground water have been purged. Record the median of the final five or more readings as the value to be reported for that site (see 6.0.3).
  - **For sites at which variability exceeds the criteria of table 6.0–1:** Allow the instrument a longer equilibration time and record more measurements. To determine the value to be reported for that measurement point or well, either use the median of the final five or more measurements recorded, or apply knowledge of the site and professional judgment to select the most representative of the final readings.

Table 6.0–1. Stabilization criteria for recording field measurements
[±, plus or minus value shown; °C, degrees Celsius; ≤, less than or equal to value shown; µS/cm, microsiemens per centimeter at 25°C; >, greater than value shown; unit, standard pH unit; mg/L, milligram per liter]

Standard direct field measurement[1]	Stablization criteria for measurements (variability should be within the value shown)
Temperature:	
Thermistor thermometer	± 0.2°C
Liquid-in-glass thermometer	± 0.5°C
Conductivity:	
when ≤ 100 µS/cm	± 5 percent
when > 100 µS/cm	± 3 percent
pH:	
Meter displays to 0.01	± 0.1 unit
Dissolved oxygen:	
Amperometric method	± 0.3 mg/L
Turbidity[2]:	
Turbidimetric method	± 10 percent

[1]Eh is not considered to be a routine or direct field measurement (see NFM 6.5). Alkalinity and acid neutralizing capacity require a titration procedure and, thus, are not direct measuments.
[2]Refer to NFM 6.7 for guidance related to turbidity units.

SURFACE WATER 6.0.2

Field measurements must accurately represent the body of surface water or that part of the water body being studied. Field teams need to select a method to locate the point(s) of measurement (6.0.2.A) and the method(s) to be used to make the field measurements (6.0.2.B).

Normally, the point(s) at which field measurements are made correspond to the location(s) at which samples are collected. Standard USGS procedures for locating points of sample collection for surface-water sampling are detailed in Chapter A4 (NFM 4) of this *National Field Manual* and in Edwards and Glysson (1999).

Properties such as temperature, dissolved-oxygen concentration, and Eh must be measured directly in the water body (in situ). Properties such as pH, conductivity, and turbidity are best measured in situ, but also may be measured in a subsample of a composited sample collected using discharge-weighted methods. Because determinations of alkalinity or acid-neutralizing capacity (alkalinity/ANC) cannot be made in situ, a discrete sample must be collected or subsampled from a composite.

6.0.2.A LOCATING POINT(S) OF MEASUREMENT

The method selected to locate the point(s) of measurement usually differs for still water and flowing water. If the water system is well-mixed and its chemistry is relatively uniform, a single sample could be sufficient to represent the water body. Often, however, multiple points of measurement are needed to determine a representative set of field-measurement values.

- Still water
  - Still-water conditions are found in storage pools, lakes, and reservoirs. Field measurements usually are made in situ at multiple locations and depths. Alternatively, pH, conductivity, and turbidity can be measured in a discrete sample or subsample (see 6.0.2.B). Measurement of alkalinity/ANC must be in a discrete sample. The location, number, and distribution of measurement points are selected according to study objectives.
    - Measurements made at discrete depths through the vertical water column must not be averaged or reported as a median value that represents the entire vertical.
    - Report the value selected to represent each point measured in the vertical as individual stations or distinguish measurements in that vertical by assigning a unique time to each measurement.

- Flowing water
  - Flowing water conditions are found in perennial and ephemeral streams. The location and the number of field measurements depend on study objectives (see Technical Note, below). Generally, a single set of field-measurement data is used to represent an entire stream cross section at a sampling site and can be useful when calculating chemical loads.
  - To obtain data representative of the section, the variability of discharge and field measurements across the stream must be known. This information is used to determine if the equal-discharge-increment (EDI) or equal-width-increment (EWI) method of locating field-measurement points should be used.

To locate measurement points:

1. Check the cross-sectional profile data of the stream site to determine the variability of discharge per unit width of the stream and of field-measurement values across the section.
   - Make individual measurements at a number of equally-spaced verticals along the cross section and at multiple depths within each vertical; or, consult previous records for the site.
   - Make in situ (6.0.2.B) field measurements for the profile.
   - Field-measurement profiles of stream variability are needed for low- and high-flow conditions and should be verified at least every 2 years or as study objectives dictate.
2. Select the EDI or EWI method to locate points of measurement (refer to NFM 4 or Edwards and Glysson (1999) to select and execute the appropriate method).
   - If stream depth and velocities along the cross section are relatively uniform, use the EWI method.
   - If stream depth and velocities along the cross section are highly variable, use the EDI method.
   - In a small and well-mixed stream, a single point at the centroid of flow may be used to represent the cross section. The centroid of flow is defined as the point in the increment at which discharge in that increment is equal on both sides of the point.

TECHNICAL NOTE: Standard USGS procedure is to use either the equal-discharge increment or equal-width increment method for locating measurement points to ensure that chemical loads can be calculated. Different study objectives could dictate different methods for locating the measurement point(s). For example, field measurements designed to correlate water chemistry with benthic invertebrates may require measurements on one or more grab samples that represent populated sections of the stream channel.

Equal-Discharge Increments (EDI)

The stream cross section is divided into increments of equal discharge. Field measurements can be made in situ at the centroid of each increment or by collecting an isokinetic depth-integrated sample at the centroid of each increment and determining the value either of each sample or of a composite of the samples. These methods result in data that are discharge-weighted (Edwards and Glysson, 1999).

- Knowledge of streamflow distribution in the cross section is required to select verticals at which measurements will be made or subsamples collected. Streamflow distribution can be based on long-term discharge record for the site or on a discharge measurement made just prior to sample collection.
- If the stream is well-mixed with relatively uniform discharge, the EDI can consist of a single vertical at the centroid of flow.

RULE OF THUMB:

Divide the stream into a minimum of four increments. More increments could be needed for a stream site that is poorly mixed.

To divide the cross section into increments of equal discharge:

1. Visually inspect the stream from bank to bank, observing velocity, width, depth distribution, and the apparent distribution of sediment and aquatic biota in the cross section. Note location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other obstructions.
2. If the channel and the control governing the stage are stable, historical streamflow data can be used to determine the measurement locations. If the channel is unstable or if no historical data are available, make a discharge measurement and preliminary field measurements across the selected section of channel.
   a. From the available discharge data, either
      - construct a graph using cumulative discharge or cumulative percent of total discharge plotted against the cross-sectional width, or
      - determine EDI sections directly from the discharge measurement note sheet.
   b. If profile values of pH, conductivity, temperature, and DO differ by less than 5 percent and show that the stream is well mixed both across the section and from top to bottom, a single measurement point at the centroid of flow can be used to represent field-measurement values of the cross section.
3. From the graph or measurement notes, determine the number and locations of EDIs and the centroids of those increments.

EXAMPLE:

If 5 increments will be used, select points of measurement by dividing the total stream discharge by 5 to determine increment discharge: in this case, each EDI equals 20 percent of discharge. The first vertical is located at the centroid of the initial EDI, the point where cumulative discharge equals 10 percent of the total discharge. The remaining 4 centroids are found by adding increment discharge to the discharge at the initial EDI centroid. The EDI centroids will correspond to points along the stream cross section where 10, 30, 50, 70, and 90 percent of the total discharge occur.

When making field measurements:

1. Select either the in situ or subsample method and follow the instructions in 6.0.2.B.
   - **In-situ method**—Go to the centroid of the first equal-discharge increment. Using submersible sensors, measure at mid-depth (or multiple depths) in the vertical. Repeat at each vertical. The value recorded at each vertical represents the median of values observed within approximately 60 seconds after sensor(s) have equilibrated with stream water.
   - **Subsample method**—Collect an isokinetic depth-integrated sample at the centroid of each equal-discharge increment, emptying the increment sample into a compositing device. Measure field parameters either in the sample collected at each increment or in a subsample taken from the composite of all the increment samples.
2. The final field-measurement value is the mean of the in situ or individual increment-sample value for all the EDI verticals in the section (the composite subsample yields a single value). (Note: for computation of mean pH, use the method described in section 6.4.3.A).
3. Enter data on field forms.

EXAMPLE:

Table 6.0–2 is an example of how mean conductivity measured in situ is calculated using the equal-discharge-increment method

- In the example, the correct value for the discharge-weighted mean conductivity is 163 µS/cm, calculated from 815 divided by 5 (the sum of the recorded median values divided by the number of median measurements).
- Note that at the midpoint of the center centroid of flow (increment 3) the median conductivity would have been reported as 155 µS/cm; if conductivity had been measured near the left edge of the water (increment 1), the conductivity would have been reported as 185 µS/cm.

Table 6.0–2. Example of field notes for a discharge-weighted conductivity measurement

[ft/sec, feet per second; ft, feet; ft^2 square feet; ft^3/sec, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; LEW, left edge of water; —, not available; REW, right edge of water]

Equal discharge increment	Percent of flow in increment	Mean velocity, in ft/sec	Width of increment, in ft	Depth of increment, in ft	Area of increment, in ft^2	Increment discharge, in ft^3/sec	Median conductivity, in µS/cm
LEW	0	—	—	—	—	—	—
1	20	2.0	22	5.7	125	250	185
2	20	2.2	11	10.4	114	250	170
3	20	2.3	9	12.0	109	250	155
4	20	3.9	5	12.8	64	250	155
5	20	3.4	10	7.4	74	250	150
REW	0	—	—	—	—	—	—

Calculation of conductivity: mean of median conductivity measurements

$$\left(\frac{815}{5} = 163\mu S/cm\right)$$

Equal-width increments (EWI)

The stream cross section is divided into increments of equal width. Knowledge of the streamflow distribution in the cross section is not required.

- In situ field measurements are made at the midpoints of each increment. Area-weighted concentrations can be computed from these measurements (table 6.0–3).
- Subsample field measurements are made in discrete samples that usually are withdrawn from a composite sample collected using an isokinetic sample and isokinetic depth-integrating method. The volume of the isokinetic sample must be proportional to the amount of discharge in each increment and measurements in subsamples taken from the compositing device result in discharge-weighted values.

To divide the cross section into increments of equal width:

1. Visually inspect the stream from bank to bank, observing velocity, width, depth distribution, and the apparent distribution of sediment and aquatic biota in the cross section. Note location of stagnant water, eddies, backwater, areas of faster than normal flow, and piers or other obstructions.
2. Determine stream width using a tagline or from station markings on bridge railings or cableways.
3. Divide the section into equal-width increments based on flow and stream-channel characteristics along the cross section, field-measurement variability from the cross-section profile, and data objectives for the study. This interval width will govern the number of verticals used, and applies also to streams in which flow is divided (for instance, in a braided channel).

RULE OF THUMB:

•In streams 5-ft wide or greater, a minimum of 10 equal-width increments is generally recommended.

•In streams less than 5-ft wide, use as many increments as practical, but equally spaced a minimum of 3 inches apart.

---

4. Locate the midpoint of the first vertical at a distance of one-half of the selected increment width from edge of water. Locate other measurement verticals at the centers of the remaining increments.

EXAMPLE:

In a stream 60-ft wide that has been divided into 15 increments of 4 ft each, the first measurement vertical would be 2 ft from water's edge and subsequent verticals would be at 6, 10, 14 ft, and so forth, from the starting point at water's edge.

When making field measurements:

1. Select either the in situ or subsample method and follow the instructions in 6.0.2.B.
   - **In situ method**—Measure at the midpoint of each equal-width increment. Using submersible sensors, measure at mid-depth in the vertical.
   - **Subsample method**—Collect an isokinetic depth-integrated sample at the midpoint of each equal-width increment, emptying each sample into a compositing device. **Use of the correct sampling equipment is critical to execute this method successfully: standard samplers cannot meet isokinetic requirements when stream velocity is less than 1.5 ft/sec.**
2. Record a value for each field measurement at each vertical. The value recorded represents the stabilized values observed within approximately 60 seconds after the sensor(s) have equilibrated with the stream or subsample water.

   EXAMPLE:

   Table 6.0–3 provides an example of an area-weighted median measurement for conductivity measured in situ.

   - In the example, the area-weighted median conductivity equals 130 µS/cm.
   - To calculate an area-weighted median, multiply the area of each increment by its corresponding field measurement, sum the products of all the increments, and divide by total cross-sectional area.
   - Note that if the conductivity reported were selected at mid-depth of the vertical of centroid of flow (section 10), it would have been reported as 125 µS/cm; if the conductivity reported were near the left edge of water, it would have been reported as 150 µS/cm.

▶ The final field-measurement value normally is calculated as the mean of the values recorded at all EWI increments, resulting in an area-weighted mean. (Note: for pH, calculate the mean using the method described in section 6.4.3.A).

▶ Alternatively for EWI, if the area-weighted median best represents integrated stream chemistry, you can report the median instead of the mean—but, be sure to document this on the field form and in the final data report (a parameter code currently is not available for median values).

Table 6.0-3. Example of field notes for an area-weighted conductivity measurement
[ft, feet; LEW, left edge of water; ft^2, square feet; µS/cm, microsiemens per centimeter at 25 degrees Celsius;—, not available; REW, right edge of water]

Section number	Cumulative percent of flow in section	Vertical location, in ft from LEW	Width of section, in ft	Depth of vertical, in ft	Area of section, in ft^2	Median conductivity, µS/cm	Product of median conductivity and area
LEW	0	0	—	—	—	—	—
1	2	2	4	1.0	4.0	150	600
2	4	6	4	2.0	8.0	145	1,160
3	6	10	4	2.6	10.4	145	1,508
4	10	14	4	3.2	12.8	140	1,792
5	16	18	4	3.5	14.0	135	1,890
6	22	22	4	4.0	16.0	130	2,080
7	28	26	4	4.5	18.0	130	2,340
8	34	30	4	5.4	21.6	125	2,700
9	42	34	4	6.0	24.0	125	3,000
10	50	38	4	5.7	22.8	125	2,850
11	62	42	4	5.1	20.4	125	2,550
12	76	46	4	4.6	18.4	125	2,300
13	88	50	4	3.5	14.0	125	1,750
14	96	54	4	1.4	5.6	135	756
15	99	58	4	1.0	4.0	140	560
REW	100	60	—	—	—	—	—

Calculation of conductivity: sum of values in last column divided by the total cross-sectional area

$$\left(\frac{27,836}{214} = 130\mu S/cm\right)$$

IN SITU AND SUBSAMPLE MEASUREMENT PROCEDURES 6.0.2.B

In situ and subsample procedures used for making field measurements are summarized in figures 6.0–1 and 6.0–2, respectively. For guidance, specific instructions, and potential interferences to the measurement method, consult the individual field measurement sections of this chapter (NFM 6.1 through 6.7).

In situ measurement

In situ measurement (fig. 6.0–1), made by immersing a field-measurement sensor directly in the water body, is used to determine a profile of variability across a stream section. In situ measurement can be repeated if stream discharge is highly variable and measurement points need to be located at increments of equal discharge. However, in situ measurements are point samples, and, thus, are not depth integrated.

Measurements made directly (in situ) in the surface-water body are preferable in order to avoid changes that result from removing a water sample from its source. **In situ measurement is necessary to avoid changes in chemical properties of anoxic water.**

- **In situ measurement is mandatory for determination of temperature, dissolved-oxygen concentration, and Eh.**
- In situ measurement also can be used for pH, conductivity, and turbidity, but not for alkalinity.

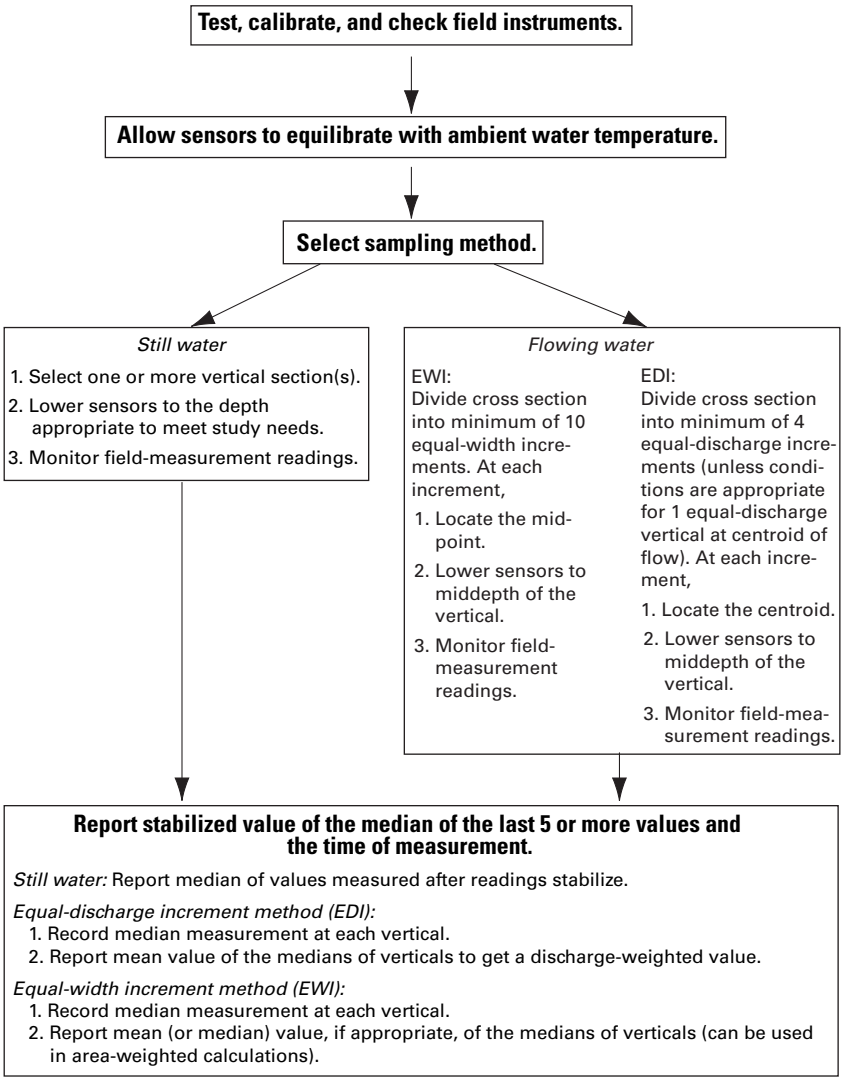

Figure 6.0–1. In situ field-measurement procedures for surface water.

Subsample measurement

Depth- and width-integrating sampling methods are used to collect and composite samples that can be subsampled for some field measurements. The same field measurements can be performed on discrete samples collected with thief, bailer, or grab samplers. Subsamples or discrete samples that have been withdrawn from a sample-compositing device or point sampler can yield good data for conductivity, pH, turbidity, and alkalinity as long as correct procedures are followed and the water is not anoxic (fig. 6.0–2).

- **Subsamples are necessary for alkalinity determinations.**
- Before using a sample-compositing/splitting device, preclean and field rinse the device in accordance with USGS-approved procedures (NFM 3; Horowitz and others, 1994).
- When compositing and splitting a sample, follow instructions for the clean hands/dirty hands technique detailed in NFM 4, as required.

Do not measure temperature, dissolved oxygen, or Eh on subsamples.

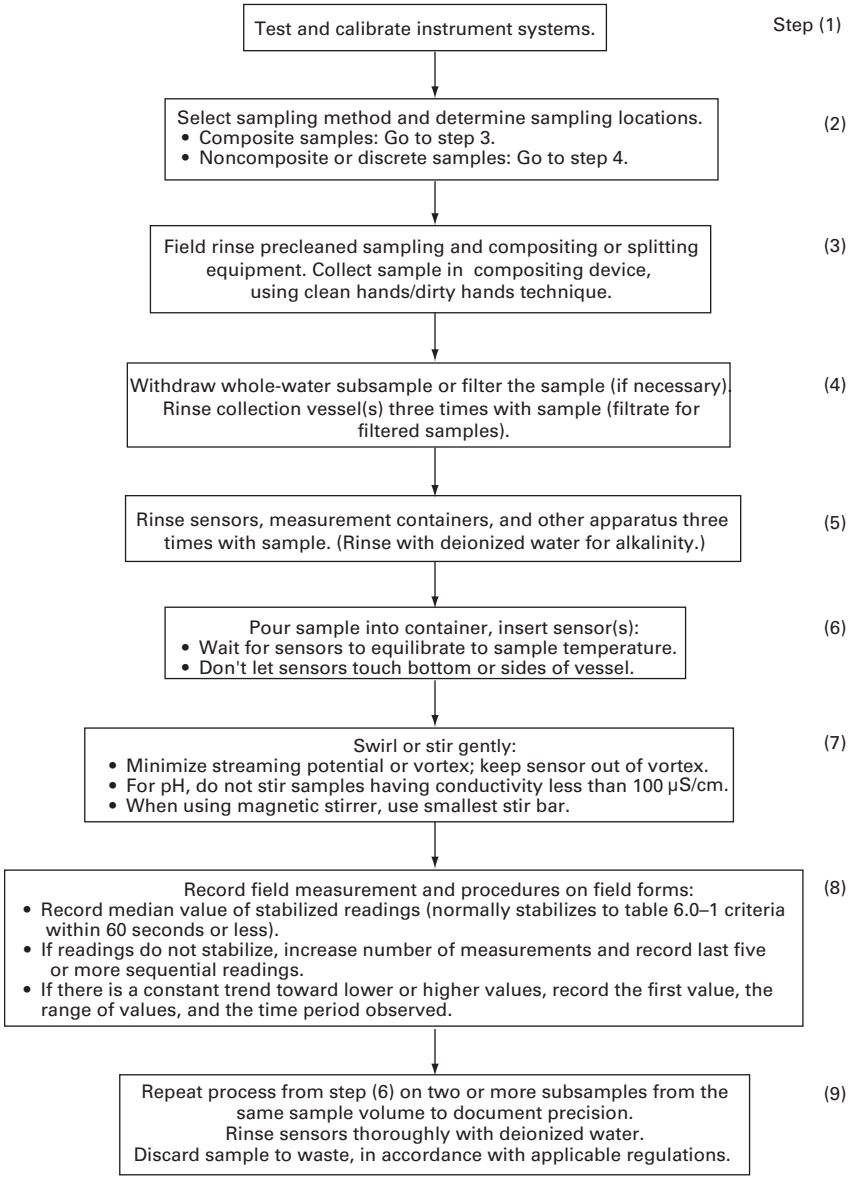

Figure 6.0–2. Subsample field-measurement procedures for conductivity, pH, and alkalinity of surface water.

GROUND WATER 6.0.3

Field measurements in ground water must accurately represent the properties of the aquifer. This generally requires purging the well of standing water, and involves setting up either a flowthrough-chamber or downhole field-measurement system (NFM 4.2). Standard USGS procedures for purging and the use of measurement systems are described below. However, the purging protocol followed and the measurement system to be used also depend on the type of well to be sampled and study objectives (detailed information can be found in Koterba and others, 1995; and Lapham and others, 1997).

- Measurements at a monitoring well
  - The standard purging procedure usually is appropriate (6.0.3.A; NFM 4.2).
  - Either a downhole or a flowthrough-chamber system can be used for field measurements (6.0.3.B). If samples will be collected, however, use the flowthrough chamber instead of the downhole system in order to avoid bias of chemical analyses from sample contact with downhole instruments.
- Measurements at a supply well (a domestic well or a municipal, industrial, commercial, irrigation, or other production well)
  - The standard purging procedure may not be appropriate (see "Exceptions to the standard purging procedure" in 6.0.3.A).
  - Identify well-construction materials and any equipment permanently installed in the well (such as a pump) that can affect the logistics and quality of the field measurement.
  - Use a flowthrough-chamber type of system (6.0.3.B).
  - Connect the field-measurement system to the wellhead at a point before the sample would pass through holding tanks, backflow pressure tanks, flow meters, or chemical treatment systems

NOTE: A measurement of the static water level is required whenever water-quality samples or other field-measurement data are collected. USGS water-level measurements must be recorded in NWIS as follows: continuous (automated) measurements must be stored in ADAPS; discrete (non-continuous) measurements must be stored in GWSI.

The final steps that must be completed involve documentating the procedures used and the measurements made. Field forms should be completed before leaving the sampling site. Report the median of the recorded field-measurement readings as the final well voume is purged.

- Record anomalies, difficulties, and adjustments on the field form.
- Record the purge volume, rate of pumping, initial and final intake locations, and time and respective reading of sequential field measurements (fig. 6.0–3).

6.0.3.A WELL PURGING

Well purging removes standing water from a well. Purging reduces chemical and biochemical artifacts caused by well installation, inadequate well development, well-construction materials, or infrequent pumping (American Society for Testing and Materials, 2005). Purging also serves to rinse and condition sampling equipment with well water.

When selecting purging equipment for monitoring wells, a portable, submersible nonaerating pump that also will be used for sampling is recommended.

- When the water table is deeper than 250 ft and (or) a large volume of water must be purged, a dual-pump system often is used: position a submersible pump downhole and a centrifugal pump at the surface. Water from the slow-pumping submersible pump is used for field measurements and to collect the sample, while the centrifugal pump operates at a higher rate to evacuate the required purge volume.
- When the water table is less than 25 to 30 ft from land surface, a peristaltic pump sometimes is used to purge small-diameter wells; a peristaltic pump or other suction-lift device should not be used if dissolved-oxygen concentrations or Eh are being monitored during purging.

- To reduce the volume and time required for purging, especially in deep wells or in wells for which purge water must be contained, an inflatable packer sometimes is set above the pump and above the screened or open interval. Packers can fail to form a complete seal between aquifer intervals, and should be used with pressure transducers to indicate water leakage.
- **A bailer is not recommended for purging.** The plunging action of the bailer can release or stir up particulates that are not ambient in ground-water flow, resulting in biased measurements and analyses. (Refer to "Subsample measurement" in 6.0.3.B for information about using a bailer.)

Steel tapes, electric tapes, or acoustic sensors are used to measure water level. An electric tape or other water-level sensor is recommended for continuous monitoring of drawdown during purging—repeated lowering of a weighted steel tape can release or stir up particulate materials and affect turbidity readings.

Standard procedure

The standard USGS procedure is to purge a minimum of three well volumes while monitoring temperature, pH, conductivity, dissolved-oxygen concentration, and turbidity.

- Sequential measurements of these parameters are used as criteria to help determine when water withdrawn from the well is representative of water flowing through the aquifer and when purging should end and sampling begin (table 6.0–1).
- The criteria normally are met within three well volumes, but well characteristics and study objectives could require removal of additional well volumes.
- The same pump should be used for purging and sampling, if possible, without stopping or removing the pump (see Koterba and others, 1995), unless the dual-pump system is used.

Exceptions to the standard purging procedure

The number of well volumes removed and the parameters used as purge criteria can be subject to data-collection objectives, well characteristics, and equipment.

- Study objectives could require a different purge volume or require sequential sampling of additional chemical constituents.
- A lesser purge volume and modified procedures are needed, for example, for wells
  - that are being pumped continuously or regularly every few hours (such as in-service public-supply wells).
  - that are pumped dry or that have a water column of less than 4 ft plus the length of the submersible pump.
  - in which sampling zones are isolated by packers.
  - in which the pump intake is installed permanently within the screened or open interval.

Before purging begins:

1. Check the well-identification number. Check the well's record of water levels, drawdown, and field-measurement variability (if available).
2. Prepare the necessary field forms, such as the well-purge record, national or study field form, and chain-of-custody record. Record the type of equipment being used.
3. Lay plastic sheeting around the well to prevent contaminating the equipment. Unlock the well housing or top of the protective casing and remove the well cap.

To purge the well:

1. Measure and record the depth to static water level (fig. 6.0–3).
2. Calculate and record the well volume as shown on fig. 6.0–3. Note that the depth to the screened or open interval and the inside casing diameter must be known to calculate well volume.
3. In a monitoring well, lower a submersible pump followed by a water-level sensor to the desired location of the pump intake. **The final pump intake position always is located at the point of sample collection.** Note that the pump position is fixed in supply wells and in monitoring wells with a permanently installed sampling system. **Lower the equipment slowly and smoothly to avoid stirring up particulates.**
   - Position the pump intake between 3 ft (~0.9 m) below static water surface and a minimum distance above the top of the open/screened interval of 10 times the well diameter (20 in. for a 2-in. well diameter), if the sample is to be integrated over the entire screened or open area of the aquifer. The location of the intake may be different when the study objective requires collecting the sample from a point within the open/screened interval or from wells in which packers are installed.
   - The water-level sensor should be a maximum of 1 ft (~0.3 m) below water surface.
4. Start the pump. Gradually increase and (or) adjust the pumping rate to limit drawdown to between 0.5 and 1.0 ft (~0.15 to ~0.3 m). Measure the water level as purging progresses.
   - If the final intake position is above the screened or open interval, the final pumping rate should be about 500 to 1,000 milliliters per minute. Do not exceed 1 ft of drawdown.
   - If the final intake position is within the screened or open interval, the final pumping rate should be about 200 to 500 milliliters per minute. Do not exceed 0.5 ft of drawdown.
   - If the pump and intake position are fixed, as in a supply well, control the rate of flow for field measurements through flow-splitting valve(s).
5. **Do not move the pump during purging or sample collection after the intake has been set at the final location.**

6. Purge a minimum of three well volumes or the purge volume dictated by study objectives (note "Exceptions to the standard three-well-volume purging procedure"). Throughout purging, monitor and record field-measurement readings (fig. 6.0–3).
   - Check for special instructions regarding field-measurement or field-analysis requirements dictated by the study objectives.
   - Contain purge water as required by Federal, State, or local regulations.
7. **As the third or last well volume is purged, when the final field measurements are recorded, adjust the purge rate to the pumping rate to be used during sampling.**
   - Record field measurements at regular time intervals—about 3 to 5 minutes apart. For deep wells, the time intervals could be 15 minutes or longer. The time intervals selected will depend on the well characteristics and hydraulic properties of the aquifer, but the intervals must be sufficiently spaced to yield results representative of aquifer properties.
   - Consult criteria for field-measurement stabilization (table 6.0–1). Field experience, understanding of the effects of hydrologic and geochemical conditions, and knowledge of data-collection and data-quality requirements often are necessary to determine the most accurate field value.

     If criteria are being met—record at least five sequential measurements and report the median value.

     If criteria are not being met—consult the study requirements and objectives. Extend the purge time if readings still do not stabilize; report the median value of the last five or more sequential measurements.

RECORD OF WELL PURGING

Date:_____ By:_____

SITE ID _____ STATION NAME _____ OTHER ID _____

WELL PURGING METHOD AND PUMP TYPE (describe):_____

TIME	WATER LEVEL below: MP or LS	DRAW-DOWN	WELL YIELD	TEMPER-ATURE	CON-DUC-TIVITY	pH	DIS-SOLVED OXYGEN	TURBID-ITY	APPROX. PUMPING RATE
HR:MIN	ft or m	ft or m	gpm or cfs	^{o}C	µS/cm	units	mg/L	input correct units	gal/min or L/min

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. If casing diameter = 2 in., well volume is 0.16 gallons per foot of casing.

FIELD MEASUREMENTS	STABILITY CRITERIA Allowable difference in sequential parameter values
NTU, Nephelometric Turbidity Units; FTU, Formazin Turbidity Units	
pH	± 0.1 standard units
Temperature, in degrees Celsius (^{o}C)	± 0.2°C (thermistor)
Specific electrical conductance (SC), in microsiemens per centimeter at 25°C (µS/cm)	± 5%, for SC ≤ 100 µS/cm ± 3%, for SC > 100 µS/cm
Dissolved-oxygen concentration, in milligrams per liter (mg/L)	± 0.3 mg/L
Turbidity (TBY)[1]	± 10%, for TBY < 100 turbidity units

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

Figure 6.0–3. Example of a field form to record well purging.

Containment and disposal of purge water must conform to Federal, State, or local regulations.

6.0.3.B DOWNHOLE, FLOWTHROUGH-CHAMBER, AND SUBSAMPLE MEASUREMENT PROCEDURES

A flowthrough-chamber system is recommended for direct field measurements (fig. 6.0–4), if samples also will be collected for chemical analysis. A downhole system is recommended if field measurements will be monitored without sampling. If samples must be bailed from the well, measure only pH and conductivity in subsamples of the bailed volume (fig. 6.0–5).

- **Downhole or flowthrough-chamber systems are required for reported values of temperature, dissolved oxygen (DO), and Eh**—Do not make these measurements in a bailed subsample or other discrete sample.
- Downhole or flowthrough-chamber systems are preferred for reported values of pH, conductivity, and turbidity.

A positive-displacement submersible pump is recommended for downhole and flowthrough-chamber systems. Lower a length of pipe to check that the well is free from obstructions before lowering a pump or downhole instrument in a well—this practice will prevent loss of costly equipment.

Downhole system

A downhole system is used for in situ field measurements. Ground water should flow upward past downhole sensors in order to obtain values representative of the depth interval being sampled; therefore, a submersible pump follows the downhole instrument. Because of this constraint, the downhole method may not be practical at wells with dedicated pumps or when using multiple equipment in small-diameter wells. Figure 6.0–4 shows the steps for downhole measurement of field parameters.

- The depth at which sensors are located depends on study objectives. If a sample is to represent ground water that is integrated over the screened interval, locate sensors approximately 1 ft above the screened interval in a 2-in. diameter well and just below the pump intake.
- Remove downhole sensors from the well before collecting samples for chemical analysis in order to prevent these instruments from affecting sample chemistry. Note that the process of removing these instruments and putting the pump back in the well causes disturbances that can affect the quality of samples subsequently collected for chemical analyses (Puls and others, 1991; Kearl and others, 1992; Puls and Powell, 1992).

Flowthrough-chamber system

A flowthrough chamber is an airtight, transparent vessel with a pressure-relief valve and either (1) grommeted ports to accommodate individual sensors or (2) a multiparameter instrument. Several types of flowthrough-chamber systems are available and can be designed for a specific measurement (for example, see NFM 6.2.2 for the description of a flowthrough cell for the spectrophotometric determination of dissolved-oxygen concentration).

When setting up a flowthrough chamber:

1. Install the chamber in-line from the pump and as close to the wellhead as possible.
   - Keep the chamber, field-measurement instruments, and tubing off the ground, shaded from direct sunlight, and shielded from wind. Spread a clean plastic sheet underneath, where tubing might be in contact with the ground.
   - Keep the tubing as short as possible.
2. Install the dissolved-oxygen sensor immediately downstream from the chamber inflow, and install the pH sensor downstream from the conductivity sensor.
3. Turn on the pump; direct initial flow to waste to avoid introducing sediment into the chamber.
   - Adjust the flow into the chamber so that a constant stream of water is maintained at the rate required for dissolved-oxygen measurements (see NFM 6.2).
   - Correct any backpressure conditions; tilt the chamber to expel trapped air.

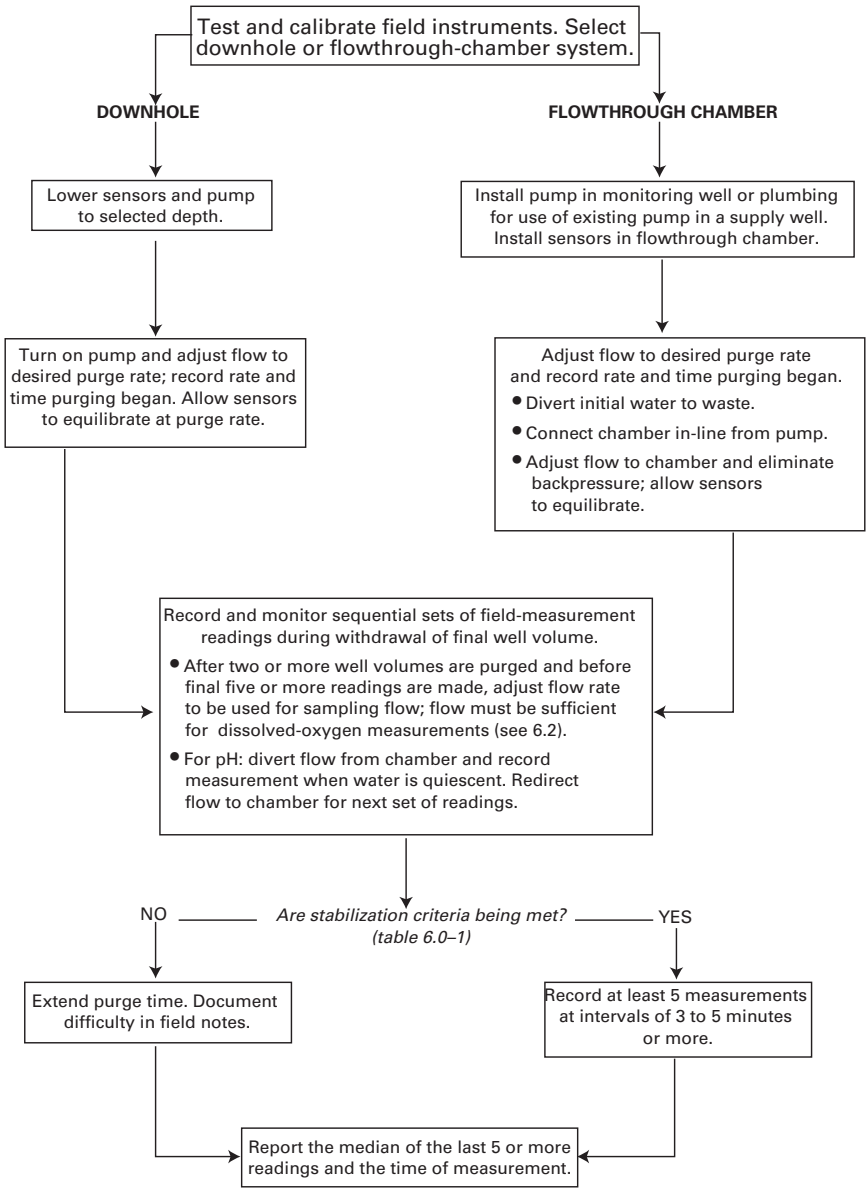

Figure 6.0–4. Field-measurement procedures using downhole and flowthrough-chamber systems for ground water.

Subsample measurement

Subsamples or discrete samples are aliquots of sample collected from a **nonpumping sampling device** such as a bailer, a thief sampler, or a syringe sampler. Measurements of field parameters made in discrete or nonpumped samples are more vulnerable to bias from changes in temperature, pressure, turbidity, and concentrations of dissolved gases than measurements using a downhole or flowthrough-chamber system.

- Subsamples can be used for conductivity, pH, and alkalinity.
- Subsamples must not be used for reported measurements of temperature, dissolved oxygen, Eh, or turbidity.
- Subsample procedures must not be used in reducing (anoxic) waters.

Figure 6.0-5 shows the steps for measurement of field parameters on a bailed sample. If collecting a sample with a bailer, use one with a double check valve. Field rinse the sampler with sample water before using. To shield the sample from atmospheric contamination, make measurements in a collection chamber or in a glove box filled with inert gas. Indicate on field forms the sampling and measurement procedures used.

Test and calibrate field instruments. Step (1)

↓

Purge well (see text for exceptions and instructions). (2)

↓

Field rinse precleaned sampler. Use clean/dirty hands technique. (3)
Lower sampler smoothly, without splashing, to desired depth of screened or open interval.
(If using bailer, double check-valve type is recommended.)
Raise sampler smoothly at a constant rate, keeping lines clean and off the ground.
Place sampler in holding stand.

↓

Withdraw subsamples from sampler. (4)

- If using bailer, insert clean bottom-emptying device with gloved hands; device should fit snugly over collection bottles and (or) measurement vessels.
- If a filtered sample is needed, filter in-line from sampler to bottle/vessel.
- Drain subsample without turbulence into collection bottles or measurement vessel.
- Rinse collection bottle(s) three times with sample (filtrate for filtered samples), fill to brim, cap tightly, and maintain at temperature of water source until measurement.
- Rinse sensors, stir bar, and measurement vessel three times with sample.
- **For alkalinity, rinse with deionized water.**

↓

Insert sensor(s) in measurement vessel. (5)

- Wait for sensors to equilibrate to sample temperature.
- Don't let sensors touch bottom or sides of vessel.

↓

Swirl or stir gently to mix sample. (6)

- Minimize streaming potential or vortex; keep sensor out of vortex.
- For pH, do not stir samples with conductivity less than 100 µS/cm.
- When using magnetic stirrer, use smallest stir bar.

↓

Record field measurement and method used on field form. (7)

- Record median value of stabilized readings (table 6.0–1).
- If readings do not stabilize, extend number of measurements and record median of at least 5 or more sequential readings.
- If there is a constant trend toward lower or higher values, record the first value, the range of values, and the time period observed.

↓

Repeat process from steps (4) through (7) on two or more subsamples from the same sample volume to document precision. (8)
Rinse sensors and equipment thoroughly with deionized water.
Discard sample to waste, in accordance with applicable regulations.

Figure 6.0–5. Subsample field-measurement procedures for conductivity, pH, and alkalinity of ground water.

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