6.0.2 SURFACE WATER

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 (1998).

Properties such as temperature, dissolved-oxygen concentration, and Eh must be measured directly in the water body (in situ). Other properties such as pH, conductivity, and turbidity often are 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.

LOCATING POINT(S) OF MEASUREMENT IN STILL AND FLOWING WATER 6.0.2.A

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.

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 (1998) 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, 1998).

- ► 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.
- ► **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.
- ► If the stream is well-mixed with relatively uniform discharge, the EDI can consist of a single vertical at the centroid of flow.

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 that for pH it is necessary to calculate the mean from the logarithm of each measurement and then convert the answer back to the antilogarithm (refer to NFM 6.4).
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.

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 (815 divided by 5)=163 µS/cm.

- 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.

Equal-width increment (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, use a minimum of 10 equal-width increments.
   - 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 for 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 was 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 was 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 (for pH, calculate the mean from the logarithm of each measurement and then convert the answer back to the antilogarithm).

► 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.

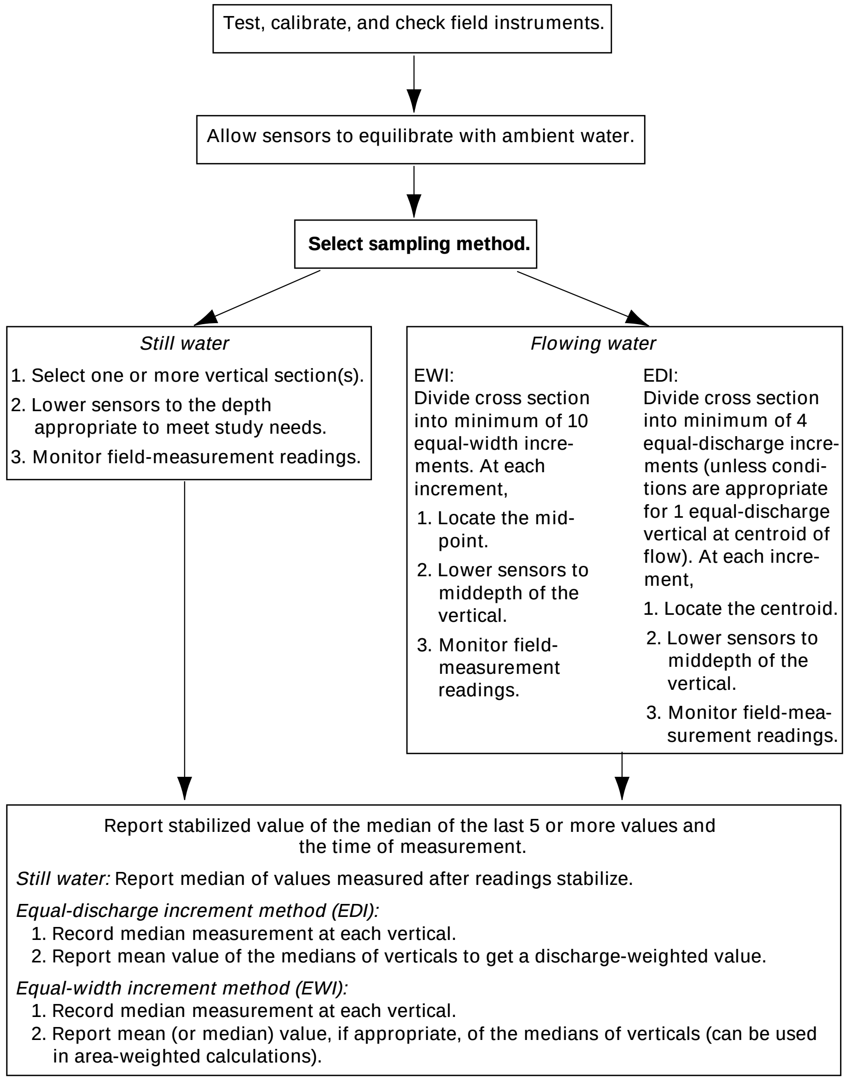

Figure 6.0–1. In situ field-measurement procedures for surface water.

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 (Horowitz and others, 1994).
- ► When compositing and splitting a sample, follow instructions for the clean hands/dirty hands technique detailed in Horowitz and others (1994), as required.

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

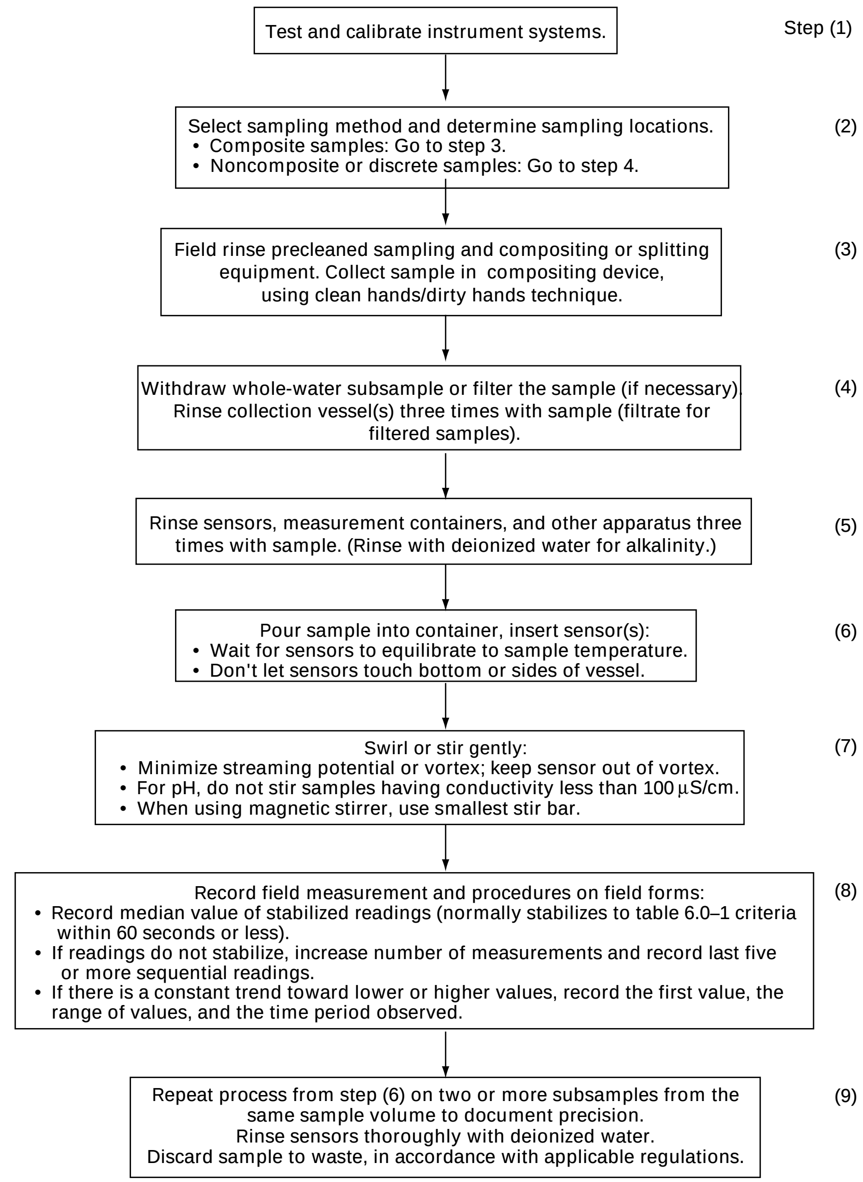

Figure 6.0–2. Subsample field-measurement procedures for conductivity, pH, and alkalinity of surface water.