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

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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.

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

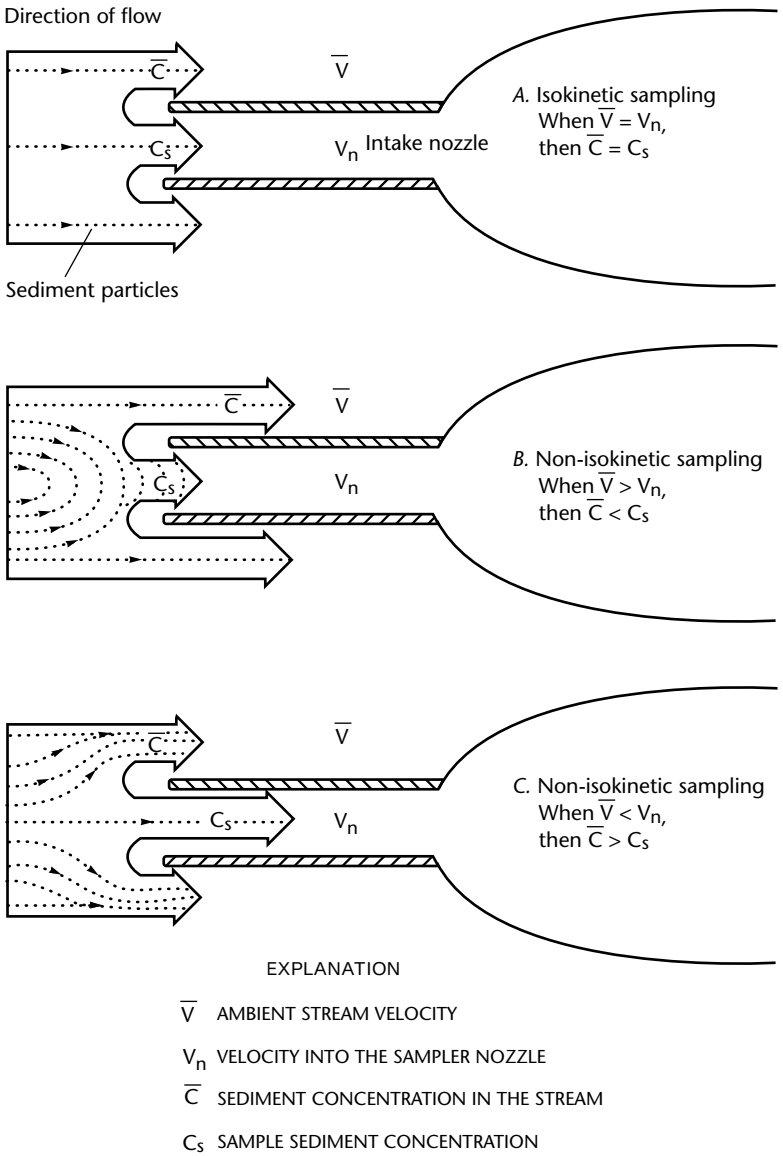


Figure 4-1. Relation between intake velocity and sediment concentration for isokinetic and nonisokinetic collection of water samples that contain particulates greater than 0.062 millimeters (modified from Edwards and Glysson, 1998, p. 13).

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

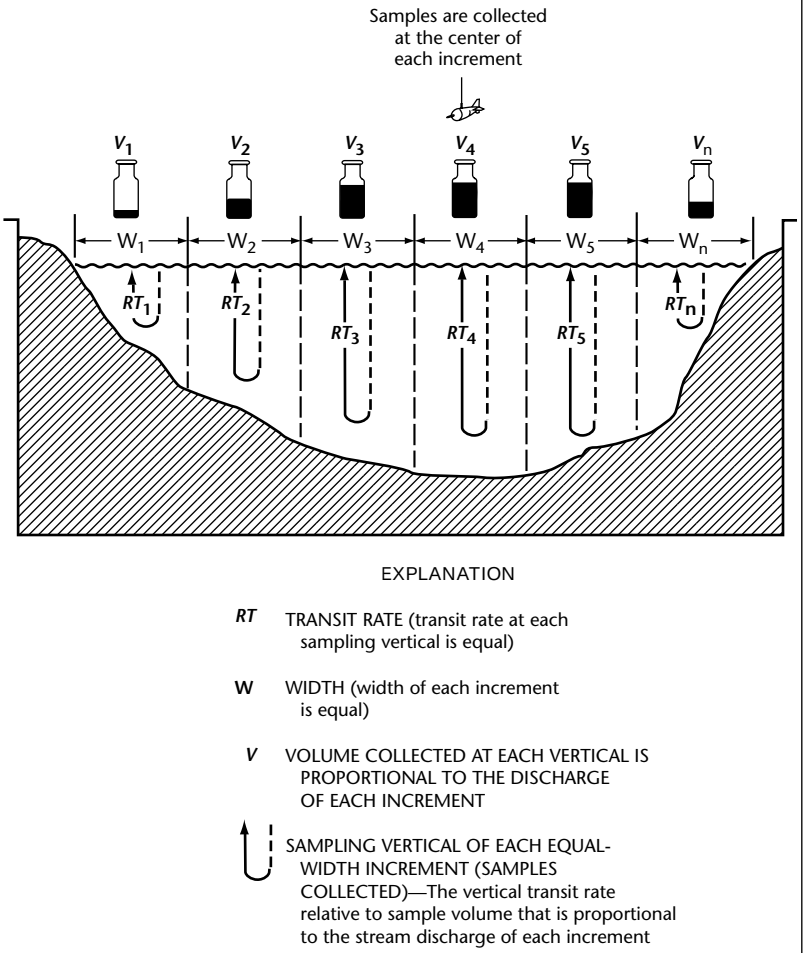
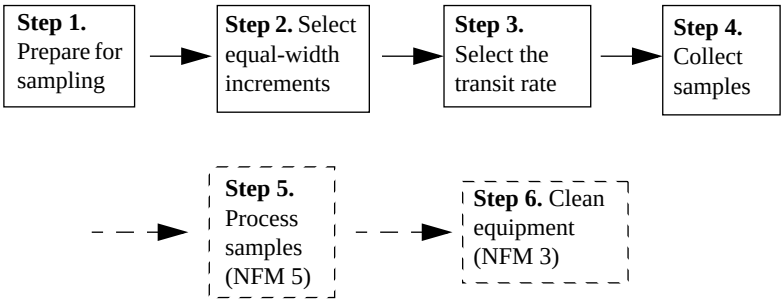


Figure 4-2. Equal-width-increment method for collection of water samples (modified from Edwards and Glysson, 1998).

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.

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.

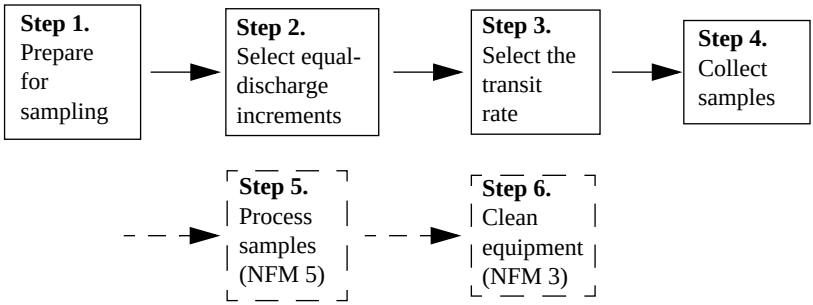
Step 6. Clean Equipment ➜ Refer to NFM 3.

- 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

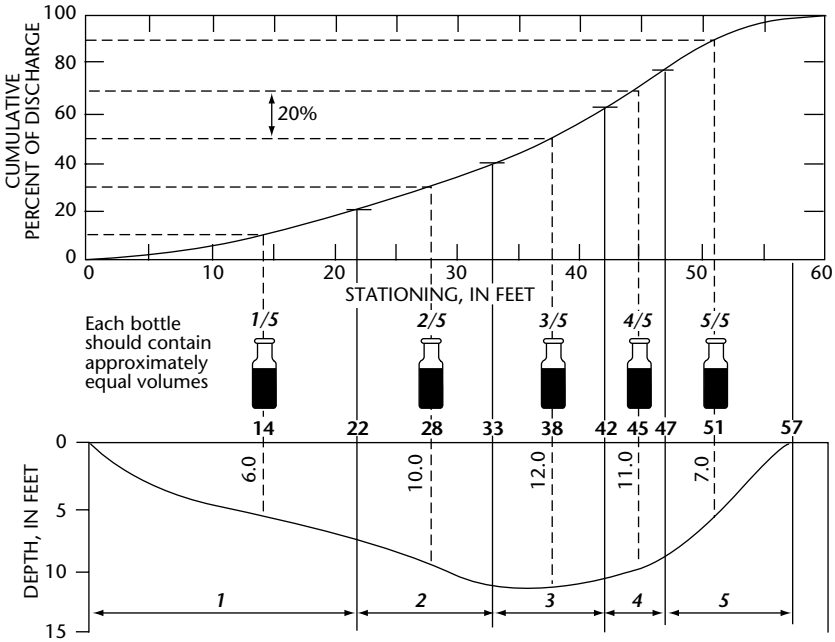
The objective of the EDI method is to collect a discharge-weighted sample that represents the entire flow passing through the cross section by obtaining a series of samples, each representing equal volumes of stream discharge. The EDI method requires that flow in the cross section be divided into increments 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.

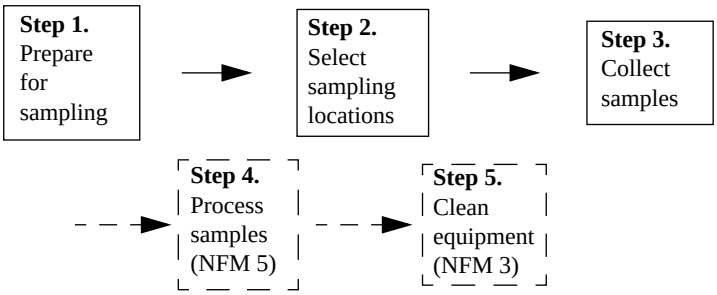
- Single-stage samplers, such as the U-59 (NFM 2) are useful for collecting samples for analysis of sediment and selected chemical constituents at stations located on streams or other locations susceptible to flash floods or where it is otherwise difficult to reach a station to manually collect samples. 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.

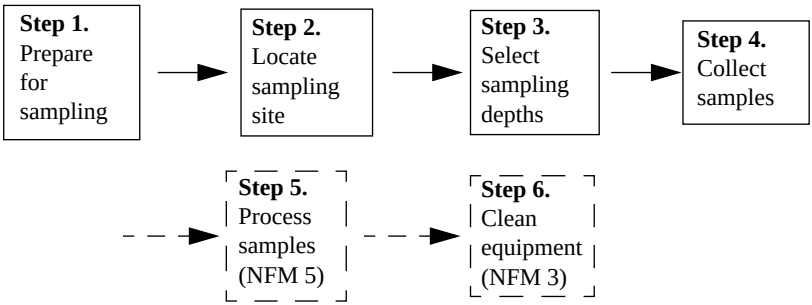
4.1.2 STILL-WATER SITES

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.