Section 4: Physical Measures

Photos Courtesy of Katie Register and the Loudoun Wildlife Conservancy

Chapter 11

Temperature

Why Monitor Water Temperature?

The rates of biological and chemical processes depend on temperature. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Aquatic organisms are dependent on certain temperature ranges for optimal health. Optimal temperatures for fish depend on the species as some survive best in colder water. Benthic macroinvertebrates are also sensitive to temperature and will move in the stream to find their optimal temperature. For fish, there are two kinds of limiting temperatures: the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages. If temperatures are outside this optimal range for a prolonged period of time, aquatic organisms are stressed and can die. Also, dramatic shifts in water temperature can cause stress to aquatic organisms.

What Do Your Water Temperature Measurements Mean?

Temperature changes can be caused by weather, removal of stream bank vegetation (which provides shade), impoundments (caused by barriers such as dams), cooling water discharge, urban storm water, and groundwater flowing into the stream. The water quality standards for water temperature in Virginia can be found in Table 11-1 below. Water temperature readings above these numbers indicate a violation of our state's water quality standards.

Table 11-1. Virginia Water Quality Standards for Temperature.

Estuarine Waters	**Nontidal Waters – Coastal / Piedmont**	**Mountainous Zones**	**Stockable Trout Waters**	**Natural Trout Waters**
Rise above natural temperature (arithmetic average over one hour) should not exceed 3°C.	32°C (maximum)	31°C (maximum)	21°C (maximum)	20°C (maximum)

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for temperature are discussed below.

Air Temperature

If air temperature is measured in addition to water temperature, then the air temperature reading should be measured prior to the water temperature. A wet thermometer can alter the air temperature reading. Air temperatures should be measured in the shade.

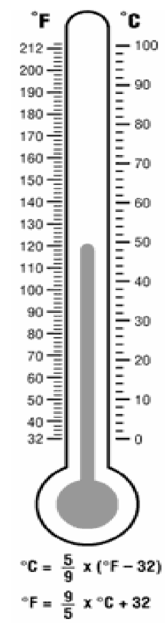


Figure 11-1. Scale for temperature conversion *(from Volunteer Estuary Monitoring: A Methods Manual, Second Edition).*

Choosing a Method

Temperature must be measured in the stream and may be measured with a thermometer or a meter. Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C). Temperature should be measured at the same place every time.

Thermometer

Alcohol-filled thermometers are preferred over mercury-filled because they are less hazardous if broken. Armored thermometers for field use can withstand more abuse than unprotected glass thermometers. Thermometer increments should be no more than 1°C.

Thermister

Thermisters can be stand alone meters or combined with other parameters, such as pH or dissolved oxygen.

> Located at the end of this chapter are procedures developed by the Alliance for the Chesapeake Bay for measuring water temperature and yearly calibration of thermometers and thermisters.

Quality Assurance/Quality Control Issues

To assure accuracy, thermometers and Thermisters should be verified annually with a National Institute of Standards and Technology (NIST) certified traceable thermometer. You should compare these instruments at varying temperatures: an ice bath, room temperature, and warm water bath. If the difference between your equipment and the certified thermometer is greater than 1º C during any of the comparisons, your equipment does not meet the Department of Environmental Quality's (DEQ) QA/QC requirements for data use in water quality assessments.

Where Can You Find a Certified Thermometer?

- DEQ Regional Office
- Local college/university
- Local EPA-certified laboratory

Summary of Water Temperature Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level (see Appendix 9)**
Field Thermometers (non-mercury)	$18.95	I, II, or III
Thermistor (usually included with pH and dissolved oxygen probes)	~$200 standalone	I, II, or III

Water Temperature Measurement- *Provided by the Alliance for the Chesapeake Bay*

Equipment: armored thermometer

Method (no bucket):

1. If you are not using a bucket, hold the thermometer by the top with the thermometer submerged in the stream.

2. Wait 3-5 minutes to allow the thermometer to equilibrate (but not long enough for water temperature to change).

3. Record water temperature to the nearest 0.5 ºC.

Method (with bucket):

If you have collected the water sample in the bucket, hang thermometer in the bucket and follow steps 2 and 3 above.

Equipment: Thermister Probe

Method:

1. Place the thermister in the waterbody being measured

2. Wait 1-2 minutes to allow the probe to stabilize. It may help to slowly move the probe side to side to provide a uniform measurement

3. Record water temperature to the nearest 0.1 ºC.

Thermometer Calibration: (for Level III compliance) - *Provided by the Alliance or the Chesapeake Bay*

Every year, thermometers and electronic probes should be validated against a NIST-certified thermometer. This is necessary to ensure the thermometers and probes are recording accurate temperature readings. The Virginia Department of Environmental Quality (DEQ) and other organizations can assist monitoring groups in this process.

Before You Begin

You will need the following materials:

1. Thermometer needing validating
2. NIST-certified thermometer calibrated within 1 year of the date of the calibration
3. hot plate or other source for heating water
4. 2 beakers or containers of water
5. clamps to suspend the thermometers
6. stir rod

Prior to starting the calibration, you will need to adjust the temperature of the water in each beaker:

a. For the first beaker, pour the water into the container and allow it to adjust to room temperature. The temperature should be between 20-25^{o}C. (Note: You can leave the beaker of water out overnight prior to validating the thermometers so that it can reach room temperature).
b. Place the second beaker of water onto the hotplate or warm up in a microwave or similar device. The final temperature should be between 32-35^{o}C. (Note: this may take 15-45 minutes if using a hot plate).

You can use the stir rod to mix hot water beaker to achieve a uniform temperature.

Thermometer physical check

Perform the following checks to the thermometer prior to calibration:

a. Check both the NIST and thermometers for nicks and scratches.
b. Check the column of both thermometers to ensure that the column does not have breaks or separations.
c. Observe to see if the NIST or the thermometer being validated has a solid line drawn or etched near the bottom quarter of the glass body. If so, this is a **partial immersion thermometer**. For a partial immersion thermometer, you should only submerge the thermometer to this line. If you do not see a line, the thermometer is a **full immersion thermometer**. You can submerge this type of thermometer into the water filled beakers to about one inch from the bottom.

Validation

Room temperature beaker-

1. Carefully remove both thermometers and place them into the beaker of water set at room temperature. Ideally, the water should be between 20-25^{o}C.

2. Allow two minutes for the thermometers to adjust to the temperature. You should observe a result between 20-25^{o}C. Do not touch or hold the thermometer with your hands or remove the thermometer from the water. Doing this will raise the temperature and give you an inaccurate reading.

3. Record the result of the NIST thermometer onto your log sheet. To read the thermometer correctly, keep it immersed in the water and look at the top of the column at eye level. Record the values to the nearest unit. Usually this is 0.2 or 0.5 ^{o}C.

4. Repeat this process for other thermometers or probes needing validation.

Hot water beaker-

1. Remove the thermometers from the room temperature beaker and immerse them into the beaker of hot water. The temperature of the water should be between 32-35^{o}C.

2. Record the NIST certified and thermometer being verified temperatures using the same procedure outlined in the room temperature beaker.

Once you have removed the thermometers, allow them to cool down to room temperature. Do not try to cool down the thermometers quickly as it may separate the column.

Compare the results between the NIST and the thermometer. If difference of temperature is less than 1.0 ^{o}C, record the difference on the log sheet and use the correction when using the now validated thermometer. It is a good idea to mark this difference on the thermometer using masking tape or other means. If the difference is greater than 1.0^{o}C, retest the thermometers. If temperatures are still off by more than 1.0^{o}C, discard and replace the thermometer.

Thermometer Validation Log Sheet

Group name: ____________________ Date of Validation: ____________________

Validated by: ____________________ NIST Cal/Val Date: ____________________

Thermometer Type or Model	Thermometer ID	NIST Reading (~Room Temp)	Thermometer Reading	Difference	Within 1 C? (Circle One)		NIST Reading (~35 C)	Thermometer Reading	Difference	Within 1 C? (Circle One)	
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO
					YES	NO				YES	NO

Chapter 12

Turbidity/Transparency

What Are Turbidity/Transparency?

Although the terms "turbidity" and "transparency" are often used interchangeably, they are different measurements. Turbidity is the cloudiness of water determined by measuring how the material suspended in water affects the water's clarity (how well light passes through the water column). Turbidity does not measure the amount of materials suspended in the water (such as soil, algae, and plankton); but it does measure the amount of light scattered by these particles. Turbid water appears murky or cloudy. Transparency, however, is the clarity (clearness) of the water determined by measuring how well light passes through the water. Both color and suspended materials can affect transparency.

Why Monitor Turbidity/Transparency?

Turbidity/transparency and total solids can be useful indicators of discharges and runoff effects from construction, agricultural practices, logging activity, and waste discharges. Monitoring these parameters may help indicate whether erosion is increasing in a watershed. Turbidity can be caused by any activity that disturbs the stream banks, streambed, or surrounding land that causes sediment runoff into the stream. Turbidity often increases during and just after rainfall, especially in watersheds with a large number of impervious surfaces (rooftops, pavement, parking lots). Stormwater runoff from impervious surfaces rapidly increases the volume and velocity of stream flow, which erodes stream banks.

Sources of Turbidity

- Excessive algal growth due to nutrient enrichment
- Soil erosion from logging, agriculture, or construction
- Stormwater runoff
- Eroding stream banks
- Disturbance of bottom sediments
- Waste discharges

High turbidity levels affect SAV and dissolved oxygen levels. Turbidity reduces the amount of light penetrating the water, reducing photosynthesis and lowering the production of dissolved oxygen. Therefore, high turbidity can reduce SAV. Water temperature also increases with high turbidity levels because suspended particles absorb heat, which reduces dissolved oxygen levels (please refer to Chapter 4). Large amounts of suspended materials can clog fish gills, reduce disease resistance in fish, lower growth rates, and negatively affect egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, smothering fish eggs, benthic macroinvertebrates and the streambed habitat. Toxins also attach easily to suspended solids. The concentration of dissolved solids (such as chloride, nitrate, phosphate, iron, sulfate, magnesium, and calcium) may affect the water balance in the cells of aquatic organisms making it difficult for them to keep their position in the water column. This will in turn affect the organism's ability to maintain the proper cell density.

What Do Your Turbidity/Transparency Results Mean?

Although there are no water quality standards in Virginia for or turbidity, this information can be useful when looking at trends and can provide information about local land use and sediment control programs. It is important to remember that turbidity/transparency does not measure the amount of suspended solids or the rate of sedimentation. Since algae can be the major source of suspended solids in estuarine waters, seasonal variations must also be taken into consideration when analyzing turbidity.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for turbidity/transparency are discussed below.

When to Sample

To gain information that would be useful for looking at trends, turbidity should be monitored relatively frequently year-round for several years. Since turbidity often increases during and immediately after a rainfall, you may consider collecting additional turbidity data to capture the effects of runoff.

Choosing a Method

Secchi Disk

This weighted disk is used to measure transparency (an integrated measure of light scattering and absorption) by lowering the disk into the water and measuring the depth where the disk disappears (Secchi depth). The clearer the water the greater the Secchi depth. Many volunteer programs in lakes or tidal, estuarine waters use the Secchi disk because it is inexpensive and easy to use. Secchi disk lines may shrink over time and lines that are marked for measurements should be calibrated regularly. Using a rope that has minimal shrinkage is also recommended. The Secchi disk is not appropriate for use in shallow, fast moving waters.

Secchi disk *(photo courtesy of Alliance for the Chesapeake Bay).*

Located at the end of this chapter are procedures developed by the Alliance for the Chesapeake Bay for measuring Secchi depth.

Transparency Tube

This is a clear, plastic tube with a pattern on the bottom (sometimes a miniature Secchi disk). Water is poured into the tube and the measurement (usually in centimeters) where the pattern disappears is recorded. Waters with extreme colors can interfere with this measurement. The readings from transparency tubes from different manufacturers cannot be compared. This instrument was developed to measure transparency in waters where the Secchi disk is not appropriate (site is too shallow, the flow is too rapid, or there is no dock or pier).

Located at the end of this chapter are procedures developed by the Alliance for the Chesapeake Bay for using transparency tubes.

Turbidity Probes

A turbidity probe usually measures turbidity in Nephelometric Turbidity Units (or NTUs). A turbidity probe can be calibrated by using known standard concentration and is used in the field to measure the turbidity of water samples.

Laboratory Analysis

Lab analysis can be used to determine turbidity

Summary of Turbidity/Transparency Methods

Method (Vendor and Model #)	Approximate Cost	Monitoring Level (see Appendix 9)
Secchi Disk	$30-$35	I
Transparency Tube (Lawrence Enterprises # TT or TTG)	$34-$49	I
Turbidity probe	$800	I
Laboratory Analysis	$5.00*	I

*This cost is based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Secchi Transparency Measurement- *Provided by the Alliance for the Chesapeake Bay*

The Secchi disk provides a convenient method for measuring light penetration below the water surface and is widely used as a basic measure of water clarity. The Secchi disk is a black and white disk attached in the center to a marked line that is used to determine the transparency or limit of visibility of the water. The line is measured and marked in decimeters (tenths of a meter) and meters. When the weighted disk is lowered slowly straight down into the water, the exact depth just before the disk disappears from view is observed. This depth is known as the "Secchi disk transparency." The less algae and silt in the water, the deeper the Secchi disk will be visible. Alternately, shallow readings will occur in water with significant amounts of suspended algae and silt.

Equipment: 8" Secchi disk with attached line (nylon or other material that does not stretch)

Method:

1. Remove sunglasses if you are wearing them and stand with the sun to your back. Try to lower the disk into a shaded area.

2. Lower the disk into the water until the disk barely disappears from sight. Note the depth reading, in meters, based on the length of line submerged. Each black mark is one-tenth (or 0.1) meter, and each red mark is one (1) meter.

3. Slowly raise the disk and record the depth at which it reappears (i.e. is barely perceptible).

4. Average the two depth readings obtained above. The average of the two readings is considered to be the limit of visibility, or index of transparency. Record this average to the nearest tenth of a meter on your data form.

Yearly Calibration:

1. Lay out the Secchi disk and line on a table with a tape measure or ruler attached to the table. Tape measures or ruler units should be in meters.

2. Measure the marks on the line. Each mark should be 0.1 meters apart.

    a. It is recommended to use cable ties as they can be cut off and replaced. Markers tend to fade over time. If adding new cable ties, tighten them on the cable as much as possible to prevent them from moving

    b. Mark 0.1 meter (10 centimeter) graduations with one color and 1.0 meter graduations in another color to help with measuring Secchi depth.

Transparency Tube Measurement- *Provided by the Alliance for the Chesapeake Bay*

Transparency tubes are a type of equipment used for measuring transparency of water in streams and rivers. They are helpful for measuring transparency in situations where the stream is too shallow for the Secchi disk to be practical and for running waters where flow is too fast that the Secchi disk cannot remain vertical. Sample water collected either directly from the stream or from the sampling bucket is analyzed.

Equipment: Transparency tube- 60 or 120 cm long with drain tube

Method:

1. Close the drain tube by squeezing the crimp.

2. Fill the transparency tube with your sample water. Water may be collected directly from the stream in the vicinity of the sampling location if the stream is too small to fill the bucket, or sample water collected in the sampling bucket may be used (See 5.4, "Collecting the Water Sample"). To collect water directly from the stream, point the top of the tube in the upstream direction and collect surface water, being careful not to disturb the stream bed. To analyze water collected in the bucket, pour sample water from the bucket water directly into the transparency tube.

3. While looking down through the opening of the tube, partially open drain crimp, slowly draw off sample (Control flow by squeezing the crimp).

4. When the black and white pattern begins to appear, immediately tighten the crimp.

5. Record the level of water remaining via the centimeter ruler found on the side of tube.

Yearly Calibration:

1. Prepare a solution of water dyed with food coloring. The recommended mixture is 50 drops of red coloring with 10 drops of green coloring in 5 quarts (1 ¼ gallons) of water.

2. Slowly pour colored solution into the turbidity tube to the top.

    a. If you are able to see Secchi pattern at bottom when tube, empty the tube and add more food coloring and try attain.

    b. If you pour in water too quickly, bubbles can form causing difficulty in reading the results

3. Slowly drain the tube until the volunteer can just make out the Secchi disk pattern.

4. Repeat steps 1-3 again to confirm results

Chapter 13

Salinity

What is Salinity?

Salinity is the amount of dissolved salts in water. Salinity of tidal rivers and estuaries gradually increases as you move from freshwater tributaries toward the ocean. Salinity is usually measured in parts per thousand (ppt). Freshwater streams and rivers have salinity levels of 0.5 ppt or less. Salinity of seawater is relatively constant at more than 30 ppt.

Why Monitor Salinity?

Salinity levels affect the distribution of plants and animals in estuarine environments. Some species can only tolerate certain levels of salinity while others may be able to adjust to any salinity ranging from freshwater to saltwater.

Salinity influences the saturation levels of dissolved oxygen. The amount of dissolved oxygen (DO) the water can hold decreases as the salinity increases. If you are using a probe to measure DO in estuarine waters, you may need to know the salinity level in order to properly calculate percent saturated DO. Salinity can have a role in increasing turbidity by causing dissolved particles in fresh water to clump together upon entering the saltwater. Salinity and water temperature determine the stratification of estuarine waters. Cold, saltwater is denser than warm, freshwater and will sink below the freshwater. Tides and the wind can mix these waters and eliminate the stratification.

What Do Your Salinity Results Mean?

Although there is not a water quality standard in Virginia for salinity, this information can be useful when you are looking at trends, distribution of plant and animals, and other water quality parameters.

Sample Collection and Test Methods

Weather and Season

During wet weather periods, freshwater enters the estuarine waters lowering salinity levels. Higher salinity levels are found during dry weather periods since less freshwater dilutes the estuarine waters allowing saltwater to intrude into tidal rivers and streams. Seasonal variations and storms also help mix these waters.

Choosing a Method

Density Using a Hydrometer

Figure 13-1. A hydrometer can be used to calculate salinity based upon the density of the water *(from Volunteer Estuary Monitoring: A Methods Manual, Second Edition).*

Hydrometers are inexpensive, fragile and very consistent over time. The hydrometer measures the specific gravity of the water sample, which is the sample's density compared to the density of freshwater. As the salinity of water increases so does its density. Specific gravity is affected by both dissolved and suspended solids; whereas, salinity is based upon dissolved solids only. Therefore, salinity readings measured with a hydrometer are higher when suspended solids are present, especially in low salinity waters.

Refractivity Using a Refractometer

A refractometer is not influenced by suspended solids like the hydrometer. As light travels from air into water, the refractometer measures the change in the light's direction. The extent of this change in direction is influenced in a predictable manner by the salinity of the water. To yield accurate results, the refractometer must be close to the temperature of the sample water.

> Located at the end of this chapter are procedures developed by the Alliance for the Chesapeake Bay for using Hydrometers or Refractometers.

Probes

Salinity can be calculated from the conductivity reading (conductivity is discussed in Chapter 14). Samples may be collected and transported to a central location for measurement when using a probe. See chapter 14 for more information on using a conductivity meter.

Summary of Salinity Monitoring Methods

Method	Approximate Cost	Monitoring Level (see Appendix 9)
Hydrometer (Greers Ferry 1.000 X 1.070) *Need jar (LaMotte #2- 2149)	$50 for hydrometer and jar	I
Refractometer	$90-$350	I
Conductivity probe	Chapter 14	I

Salinity Measurement- *Provided by the Alliance for the Chesapeake Bay*

Equipment: LaMotte Hydrometer #3-0025

Method:

1. Fill plastic hydrometer jar about 3/4 full with water to be tested.

2. Hang the thermometer in the jar.

3. Lower hydrometer into the jar. Allow it to float.

4. Read and record temperature in jar.

5. Read and record temperature in hydrometer jar.

6. Read and record specific gravity to the fourth decimal place.

7. When reading the hydrometer, it is easier if you are eye level with the hydrometer. Note that the water climbs the hydrometer stem and should be read at the water level not the point where it climbs.

8. Record your temperature and salinity readings.

To calculate Salinity:

Refer to the table provided in the LaMotte hydrometer instruction booklet. Follow the example below.

Example:

Observed hydrometer reading is 1.0110, and the water temperature in the hydrometer jar is 25.5ºC. Locate observed density of 1.0110 on the left hand column of Table 1 in the LaMotte hydrometer instruction booklet. Follow the row across until finding the 25.5ºC column. The point at which the row and column meet is the resulting salinity of the sample, in this case 17.0 ppt. Observed densities and temperatures falling between those shown in the table may be interpolated.

Salinity Measurement- *Provided by the Alliance for the Chesapeake Bay*

Equipment: Refractometer

Calibrate Your Refractometer*

* The refractometer must be calibrated before taking salinity measurements.

1. Check the refractometer with distilled water. If it does not read 0 o/oo, you must calibrate the instrument. DO NOT PERFORM CALIBRATION IN THE FIELD. Calibration must take place in controlled environment at approximately 20 ^{o}C (room temperature) using distilled water of the same temperature.

2. Lift the cleat plate and add 1-2 drops of distilled water to the oval blue prism. Hold the prism at an angle close to parallel so the water drops will not run off.

3. Close the plate gently. The water drops should spread and cover the entire prism. Repeat the process if there are any gaps or if the sample is only on one portion of the prism.

4. Look through the eyepiece. If the scale is not in focus, adjust it by turning the eyepiece either clockwise or counterclockwise.

5. The reading is taken at the point where the boundary line of the blue and white fields crosses the scale.

6. If the reading is not at “0” turn the calibration screw with the included screwdriver while looking through the eyepiece until the boundary line falls on “0.”

7. When the measurement is complete, the sample must be cleaned using tissue paper and distilled water.

NOTE: The refractometer needs to be at the same approximate temperature as the sample water. If the refractometer has been sitting in an air-conditioned environment prior to sampling, allow it to warm to the outside air temperature.

Method:

1. Rinse the refractometer with water sample.

2. Apply drops from water sample on refractometer and hold up to light to read salinity (right side of circle).

3. Record as parts per thousand (o/oo) using the scale located on the right hand side of refractometer view scope.

Chapter 14

Conductivity

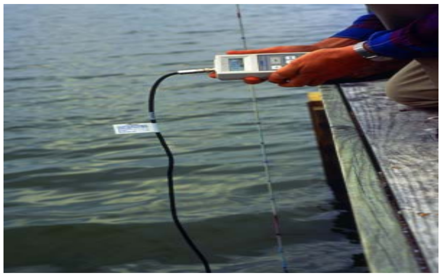
What is Conductivity?

Conductivity is the ability of water to pass an electrical current. Conductivity is affected (raised) by inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge); and sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Oils and many organic compounds do not conduct an electrical current very well and therefore, do not affect conductivity. When the conductivity value is corrected to 25^{o}C the corrected value is called specific conductance. Conductivity usually is reported as specific conductance and is measured in micromhos per centimeter or microsiemens per second.

The geology of the area through which a stream flows is one of the most important factors affecting conductivity. Streams in areas with granite bedrock usually have lower conductivity levels because granite is composed of relatively inert material that does not conduct an electrical current very well. Alternatively, streams in areas with clay soils usually have a higher conductivity because of the presence of materials that conduct electrical currents. Ground water inflows can have the same effects depending on the bedrock they flow through. Warmer water has a higher conductivity than colder water.

Why Monitor Conductivity?

Conductivity is a useful measure of general water quality. Each stream generally has a relatively constant range of conductivity. Once you establish the baseline conductivity range for a stream, you can compare regular conductivity measurements. Significant changes in conductivity may indicate a discharge or another source of pollution is affecting the stream.



Volunteer measuring conductivity with a meter *(photo courtesy of Alliance for the Chesapeake Bay).*

Discharges to streams can affect the conductivity depending on the type of discharge. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate (which would conduct an electrical current well). An oil spill, however, would lower the conductivity. Heavy rains also lower the conductivity since rainwater has a very low conductivity.

What Do Your Conductivity Results Mean?

Although there are no water quality standards in Virginia for conductivity, this information can be useful when you are looking at trends and general water quality. As discussed in the section above, significant changes in conductivity measurements can indicate potential problems that may need further investigation.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Conductivity may be measured in the field or samples may be transported to a laboratory for determination with a probe.

Conductivity probes should be calibrated with conductivity standards for the expected range in the field. Additionally, the calibration should be confirmed at the end of the sampling day (this is referred to as a "post check") to determine if the probe has drifted during the sampling day. The post check should be conducted similar to the calibration without pressing the calibration button.

Located at the end of this chapter are instructions and a sample calibration log sheet developed by DEQ for using conductivity probes.

Summary of Conductivity Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level (see Appendix 9)**
Probe (a multi-parameter meter is more cost-effective than a single parameter meter)	$60-$1000 ~$7500.00 (multi-probe)	I

Calibrating Conductivity Probes and Meters- *Provided by the Virginia Department of Environmental Quality*

Equipment: Various models of conductivity probes and meters

Most probes that test for conductivity use a pre-made calibration solution with a specific conductivity value. The probe is immersed in the solution and calibrated to the value of the solution. It is good to use a calibration solution concentration similar to what you may find in the field to ensure accuracy.

Date- Record the date of calibration. Calibration must be done each day you perform samples.

Temp C Pre Cal- Temperature of the probe while you are calibrating the probe.

Cond Pre Cal- Write down the conductivity listed on the probe when you immerse the probe into the conductivity solution and record the value prior to calibration.

Cond Cal Solution (mS/cm)- Record the conductivity solution that you will use to calibrate the probe. The standard unit for these solutions is in microsiemens per centimeter (mS/cm) but probes may use different units.

Cond to Cal- Write down the conductivity reading after you have calibrated the probe in the solution. The probe should be very close to the calibrated buffer solution but may be off by a couple of units.

Temp C Post Check- Record the temperature of the probe at the end of the day when you are performing the calibration check.

Cond Post Check- Record the conductivity value of the probe you place the probe into the conductivity calibration solution. The value should be near the morning calibration solution.

Difference m/S- DEQ does not have specific standard to know if the probe is functioning properly or not. However, the standard rule of thumb is if the probe difference is less than 10.00%, you should be confident of the probe values. To calculate the **percent difference** use the formula found under QA/QC section of Appendix 17.

Initial- Please initial the person calibrating and using the probe for your records. This is good to know incase something happens to the probe that you may not be aware of due to someone else is using it.

Notes- Space provided for any notes or comments regarding the probe.

Conductivity Probe Calibration Form

Group Name: **Probe Model:**

<10% Difference: Probe OK **>10% Difference: Flag data and service probe**

Date	Temp C in Morning	Cond Before Cal	Cond cal solution (mS/cm)	Cond to Cal	Temp C End of Day	Cond at End of Day	Difference m/S	Initials	Notes
1/1/2004	20.4	134	147	147.1	20.6	150	**101.97%**	JEB	This is an example
1/2/2004	22	140	147	147	20.1	125	**85.03%**	JEB	This is an example

Chapter 15

Stream Flow

What is Stream Flow?

Stream flow (discharge) is the volume of water that passes a given stream cross section (total width of stream) within a given period of time. Flow is measured by determining the depth and width of a stream and the velocity (speed at which water travels). The area (width multiplied by depth of a stream) multiplied by the velocity gives the discharge. Flow is affected by weather (increases during rain events), seasons (decreases during summer due to evaporation and uptake by vegetation), water withdrawals, water discharges, and the groundwater table level.

Why is Stream Flow Important?

Stream flow impacts water quality and the living organisms and habitats in the stream. The amount of pollution a stream can receive without significantly affecting the water quality partially depends upon the stream flow. Swiftly flowing, large rivers have a greater capacity to dilute pollution than small streams. Stream velocity, which is partly determined by the volume of water in the stream, affects the kinds of organisms that live in the stream (some organisms prefer faster flowing streams while others prefer slower flowing streams). Sediment entering slow flowing streams will settle quickly, while sediment in fast flowing streams will remain suspended longer. Dissolved oxygen is also affected by stream flow since fast moving streams are better aerated, which results in higher dissolved oxygen levels.

What Do Flow Measurements Mean?

Since flow is a function of water volume and velocity, it is usually expressed as cubic feet per second (ft^3/sec). Stream flow is needed to calculate how much of a pollutant the stream can receive without violating a water quality standard.

Flow data collected by volunteer monitoring programs is not typically used for TMDLs and permit applications. Data users that generally use flow data for scientific analysis (rather than permitting or other legal matters) have demonstrated an interest in any flow data. Potential uses include: conducting minimum in-stream flow analysis; relating flow measures to Wolman Pebble Counts (and Riffle Stability Index develop by the United States Forest Service); and relating flow measures to benthic macroinvertebrate populations.

Measurement Considerations

When considering measuring flow in your watershed, it is recommended that you first determine if your watershed has a stream gauge collecting flow data operated by the Department of Environmental Quality (DEQ) or the U. S. Geological Survey (USGS). USGS and DEQ work cooperatively to maintain a network of approximately 161 continuous stream flow gauging stations across Virginia. By going to the USGS Water Resources website at http://va.water.usgs.gov, users can find flow data for most of these stations which can be found in real-time (updated every 1-4 hours). The flow of most streams in Virginia is not determined on a consistent basis. In most cases where real flow data does not exist, flow is estimated by interpolating flow data from an existing gauge to the stream in question. DEQ and USGS measure flow using methods derived from USGS (as outlined in Rantz, S.E., and others, 1982, *Measurement and Computation of Streamflow: Volume 2. Computation of Discharge.* U. S. Geological Survey Water-Supply Paper. 2175).

The Virginia Save Our Streams Program (VA SOS) evaluated how flow measures are collected across the country and how flow measures collected by volunteers can be used. From this research, VA SOS found that flow is not commonly measured by citizen monitoring programs due to the difficulty in obtaining data that is useful to water quality professionals. It is important for volunteer monitoring programs to obtain the most accurate estimate of stream flow possible with the equipment and expertise of the organization.

Located at the end of this chapter are instructions provided by DEQ on how to perform basic stream flow measurements.

Summary of Stream Flow Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level (see Appendix 9)**
Estimate using float and cross sectional area, length, and velocity	Negligible (most items readily available	I
Flow Meters	$300-$1500	I

Flow Measurement Guide- *Provided by the Virginia Department of Environmental Quality with material from the United States Environmental Protection Agency*

Caution! Measuring flow may require entering the stream. Do not perform this measurement if the stream is deep or has fast flowing water. In addition, if the stream is located on private property, seek landowner permission. Follow all safety guidelines as outlined in Chapter 1.

Materials you will need:

1. String or rope
2. Two stakes and hammer
3. Tape measure (at least 20 feet but preferably 50 to 100 feet)
4. Waterproof yardstick or tape measure to measure stream depth
5. Orange or small stick that will float in the water or flow meter
6. Stopwatch, notepad, pen or pencil
7. Waders, hip boots, or sneakers that you won't mind getting wet

Selecting a Site

Select a segment of stream that can be accessed safely and has a long straight section of at least 20 feet with a minimum depth of six inches. Good locations are near bridges, but other good locations are along riffles or stream runs. If possible, it is recommended to set up a flow station at or near a sampling station so you can use stream flow data with your sampling program.

Establishing a Transect

1. Observe the banks where you will set the stakes. Use the stakes and drive them into the ground where you believe the bank ends. Usually this is marked by dry ground with grass or shrubs growing and is free of debris

2. Tie the string taught between both stakes. Mark the string starting from one bank going towards the other with twist ties or markers. These marks will be where you perform the transects. The recommended minimum number of segments should be three. Most monitoring programs perform transects every two feet. Figure 15-1 shows a general transect scheme.

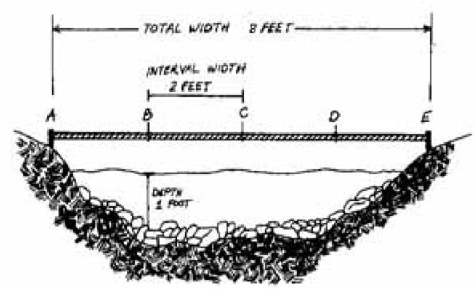


Figure 15-1. Stream transect *(from Volunteer Stream Monitoring: A Methods Manual, Second Edition).*

3. Record stream depth at each transect mark.
   Record the depth of water from the bottom of the stream at each mark. Record 0 if there is no water at a transect mark. You can also record the total height from the bottom of the stream to the transect line to determine the bank capacity of the stream.

4. To calculate the average depth of the stream, average your transect values and then multiply this value by the stream width.

Measuring Velocity

Using an Orange or Other Floating Device

1. Station one volunteer at the transect site with a stopwatch. Go a measured distance upstream from the transect site (usually 20 to 50 feet). The longer the distance, the more accurate the results.

2. Hold the float in the stream where the greatest amount of water flows. Most often, this is the middle of the stream.

3. Release the float when the downstream volunteer is ready to start timing with the stopwatch.

4. Time the float until it reaches the transect site. Discard results if the float became entangled with debris or stopped due to running aground.

5. Retrieve the float.

6. Repeat steps 1-4 to make at least three observations.

7. Average results to get the average rate of flow.

Using Flow Meter

1. At each transect point; place the flow meter in the stream as specified by instructions provided by the manufacturer.

2. Count the number of clicks or report the number of revolutions the flow meter records for 1 minute.

3. Repeat steps 1 and 2 at each transect station.

4. Determine the rate of flow based on the manual provided by the manufacturer. Often the result will be feet per second or meters per second.

Calculating Stream Flow

Calculating stream flow using oranges or similar floats, use the following formula

Flow = ALC / T

A =	Area of wetted depth (average stream depth x stream width)
L =	Distance covered by float run
C =	0.9 if the streambed is smooth (silt, sand, or bedrock) 0.8 if the streambed is rough (rubble, stones, gravel)
T =	Average time of float run

Example: A= 10 ft^2, L =100 ft, C= 0.8, and T =60 seconds

Flow = (10 ft^2 x 100 ft x 0.8) / 60 seconds

Flow = 800 cubic feet / 60 seconds = **13.34 ft^3/sec**

Calculating stream flow using flow meters, use the following formula

Flow = AMC

A =	Area of wetted depth (average stream depth x stream width)
M =	Measured flow rate based on average flow meter readings
C =	0.9 if the streambed is smooth (silt, sand, or bedrock) 0.8 if the streambed is rough (rubble, stones, gravel)

Example: A = 5 ft^2, M = 1.2 feet per second, C = 0.9

Flow = (5 ft^2 x 1.2 ft/sec x 0.9)

Flow = 5.40 ft^3/sec

Chapter 16

Visual Stream Assessments (Stream Walks)

What is a Visual Stream Assessment?

A visual stream assessment is basically a "stream walk" to evaluate stream health by assessing the physical habitat and potential impacts along a stream channel. A stream walk may be done on foot or by using a boat or canoe depending on the stream.

Why Conduct a Stream Walk?

Conducting a stream walk can produce valuable information about your stream. You may wish to conduct a stream walk prior to water quality monitoring to determine where to focus monitoring efforts. A stream walk may be performed in conjunction with water quality monitoring to help you formulate some theories about what may be impacting the monitoring data. Some stream walks may be conducted to determine potential impacts on stream health with no plans of monitoring.

How Can You Use the Information from a Stream Walk?

Stream walks may collect qualitative (such as rating erosion) or quantitative (such as mapping pipe outfalls) information which will ultimately determine the use of the information gathered. This information can be used to establish baseline conditions and then later stream walks can document changes over time. Some organizations may use the information to determine areas where best management practices (BMPs) are needed. BMPs are pollution control techniques used to reduce pollution from agriculture, timbering practices, construction, marinas, and stormwater. For impaired streams, the stream walk information may be useful background information for developing Total Maximum Daily Load (TMDL) Plans and TMDL Implementation Plans.

How Do You Conduct a Stream Walk?

There are several methods utilized for conducting stream walks, which are based upon similar elements. These methods often are adapted specifically to the stream and the goals of the organization conducting the stream walk.

The James River Association (JRA) developed a *Physical Assessment Guide* based upon a number of methods, including *Streamwalk* (developed by the U. S. Environmental Protection Agency's (EPA) Regional Office in Seattle, Washington.

> For more information on the Physical Assessment Guide, please contact the James River Association at (804) 788-8811 or www.jamesriverassociation.org

The goal of this guide is to develop a method specific for Virginia that can be adapted as needed by anyone interested in conducting a stream walk. This method is primarily a visual observation of stream habitat and physical attributes.

Other methods used in Virginia include: a protocol used by the Mattaponi and Pamunkey Rivers Association (contact information is in Appendix 1) based on a Maryland Department of Natural Resources protocol and a U. S. Department of Agriculture (USDA) protocol[1]. In general, stream walk protocols require that you walk, canoe, or boat along a defined stretch of stream while observing water and land conditions, land and water uses, potential pollution problems and changes over time. These observations typically are photographed and recorded on maps and data sheets.

[1] U. S. Department of Agriculture. 1998. *National Water and Climate Center Technical Note 99-1: Stream Visual Assessment Protocol*. December.

Chapter 17

Riparian Forests and Stream Health

This chapter has been excerpted and adapted, with permission, from Austin, Samuel H. 1999. *Riparian Forest Handbook 1*, Virginia Department of Forestry, December.

What is a Riparian Forest and Why is it Important?

A riparian forest is simply a streamside forest. The benefits of riparian forests are numerous, from protecting the physical stream environment to removing or transforming nutrients, sediments and pollutants. Overall, riparian forests lead to improved water quality.

Riparian forests protect the physical stream environment in a number of ways:

- Riparian forests help reduce fluctuations in water temperature and regulate light levels reaching a stream resulting in a more stable habitat for plant and animal life.
- Riparian forests provide woody debris for increased habitat diversity for benthic macroinvertebrates and fish.
- Leaf litter and algal (microscopic plant) production, the two primary sources of food energy inputs to streams, are intimately tied to the presence of riparian forests. Studies show that the algal community of a stream well-shaded by older trees is dominated by single-celled algae (diatoms) throughout the year. Streams in deforested areas often contain many thread-like (filamentous) green algae, and few diatoms. While some macroinvertebrates such as crayfish readily consume filamentous green algae, most herbivorous species of stream macroinvertebrates have evolved mouth parts specialized for scraping diatoms from the hard surfaces and cannot eat filamentous algae. Streamside deforestation is one factor that can cause macroinvertebrate diversity to decline.
- Absence of a streamside forest can change channel morphology (the dimension, pattern, and profile of a channel) resulting in habitat loss.

Healthy forest streams have a stable dimension, pattern, and profile that fit the natural landform of the surrounding landscape. Stable natural channels tend to be sinuous and relatively narrow with little exposed or eroding stream bank. They also have access to an active flood plain. Without trees, stream banks may erode creating an unnaturally wide channel. Water velocities may increase as water moves without woody debris to absorb the energy. Faster water combined with altered channel shape can cause bank scour, stream straightening, and excess sediment deposition in the streambed. Each of these can create a degraded environment that supports fewer aquatic plant and animal species.

Eroded stream bank *(photo courtesy of Alliance for the Chesapeake Bay).*

Stream systems are dynamic, but the change in stable stream systems occurs very slowly within the context of the landscape. Throughout history, humans altered the landscape causing profound effects on the landscape, streams, and rivers. Sections of streams and rivers within many watersheds shifted from a stable geometry to an unstable geometry. These adjustments continue today. The effects of human activity within the watershed are pronounced and visible on the landscape. As land is cleared, a cycle of events evolves that continues to degrade the stream system.

Why Evaluate Riparian Forests?

Evaluation of your stream's riparian forest may require additional training and technical expertise. However, this activity may be particularly rewarding for volunteer organizations interested in taking water quality monitoring to another level - restoration.

How Can You Use the Information from Your Evaluation?

The Virginia Department of Forestry (DOF) developed *Riparian Forest Handbook 1* along with a companion computer disk to guide you in evaluating a portion of a stream that you may wish to restore. There are regulations and permits required in most localities that pertain to stream restoration. It is strongly recommended that volunteer organizations conduct these evaluations and any restoration work with the assistance of a professional organization, such as a local government or local soil and water conservation district. The computer disk contains programs to assist you in characterizing your stream. Information from your measurements can help you select appropriate restoration activities. Restoration activities include:

> The *Riparian Forest Handbook 1* and companion programs may be obtained by contacting the Virginia Department of Forestry at (434) 977-6555.

- Exclusion: Limiting activity near the stream, such as fencing out livestock.
- Planting: Establishing trees along the bank of a stream.
- Channel Modification: Changing the shape of the channel to restore its natural meander, width and depth.

How Do You Evaluate Riparian Forests?

The aforementioned handbook and companion computer disk provide a detailed methodology to evaluate a riparian forest. For evaluating riparian forests, the handbook describes how to measure the departure from desired conditions using three benchmarks (discussed in detail below): the three zone riparian buffer; normal values of stream dimension, pattern, and profile; and normal values of stream particle size and distribution. In any investigation of the departure from desired conditions, it is important that measurements are made and compared for all three benchmarks.

First, select a stream area to evaluate while considering the questions in Chapter 1. As with conducting water quality monitoring, you should research existing information about your stream before collecting your measurements. Take time to review regional climate data, geology, land types, vegetation, historic land use and any forest plan guidance.

Benchmark 1: Streamside Vegetation in the 3 Zone Riparian Buffer

The 3 zone riparian buffer is an accepted minimum standard for vegetation adjacent to streams and rivers. The area immediately adjacent to the stream (Zone 1) should be comprised of larger woody plants and tress. The roots of this vegetation provide structural support for the stream bank. Zone 2 (the next 60 feet beyond Zone 1) should be a contiguous forest to filter sediments and nutrients from runoff. Beyond Zone 2 should be an area of contiguous forest, perennial grasses, or non-woody plants. To evaluate this benchmark, you will determine the dominant type of plant cover and the density of that cover.

Benchmark 2: Stream Channel Dimension, Pattern, and Profile

Measurements of stream dimension (shape of stream when viewed in cross-section), pattern (shape of stream when viewed from above), and profile (shape of stream when viewed from the "side" along its gradient, i.e. pools and riffles) are used to determine if a stream has a stable "hydrology" and "geology." A stable stream migrates slowly across its valley over thousands of years. Having evolved slowly in an undisturbed landscape, the dimension, pattern, profile, and water regime of a stream achieve a dynamic equilibrium within the surrounding environment. This equilibrium is an integration of the landscape and historic rainfall patterns upstream.

The first step is to determine hydraulic geometry by measuring a cross-section and a longitudinal profile of the stream channel, using surveying equipment. Calculations based upon these measurements (the software for the *Riparian Forest Handbook 1* includes a program that makes the calculations) are used to categorize the stream according to the Rosgen stream classification system. This classification system is commonly used to group streams with similar configurations.

Benchmark 3: Stream Channel Particle Size Distribution

In addition to streamside vegetation and hydraulic geometry, the sediment load of a stream is a useful benchmark of stability. As a stream system evolves over time, it develops a characteristic set of sediment particle sizes in the streambed. These particles move through the channel over time. The quantities of each size of material depend on the geology of the watershed and the energy of water flow in the system. In an undisturbed stream system, the distribution of particle sizes indicates the natural sediment load of the streambed (known as "bed load"). Any abrupt change in vegetation, land surface features, or length, width, depth and shape of portions of the stream channel can cause streams to adjust to recapture a stable shape. A frequent consequence of these adjustments is a shift away from the normal sediment particle size distribution. A pebble count (where particles are selected and measured) is typically used to determine particle size distribution.