Choosing Parameters to Support Your Questions

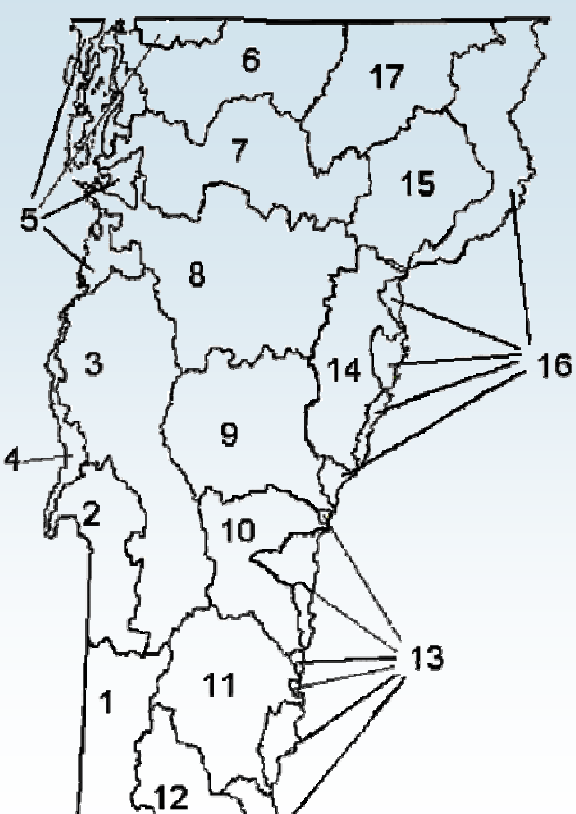
This section will show you how to:

- Find information to research your chosen waterbody and watershed.
- Select parameters to monitor that will answer your initial question.

Now you will begin to design the specifics of your monitoring plan by choosing the parameters you will monitor. Selecting parameters is a critical step in monitoring program design because you will need to choose ones that are appropriate for answering your "why" question and purpose ("what" you do with the monitoring results).

Learn what is already known about the waterbody and watershed

A volunteer monitor's starting point is not from a particular lake or stream, but from that waterbody's watershed. Collect as much background information about the watershed as possible, depending on your particular purpose and intended data use. Some purposes will require a great deal of detail, while others will require little detail. You may want to include information such as geology and soils information, land uses, watershed boundaries and drainage patterns, known water quality and aquatic biota, locations of point source discharges such as wastewater treatment plants, rainfall records, stream flows and lake levels.



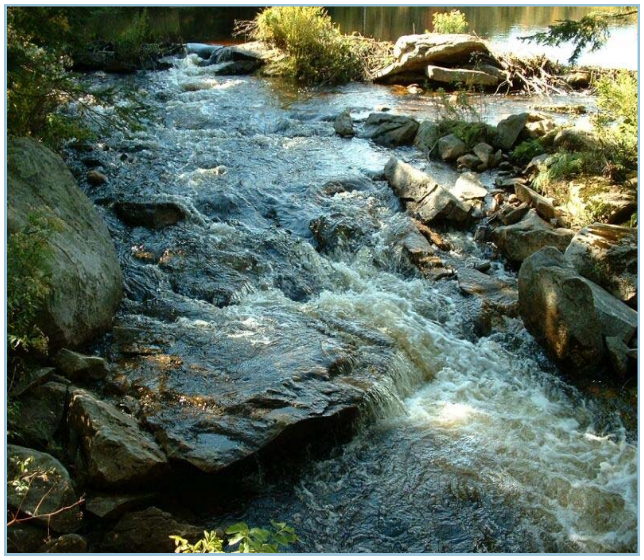
Vermont's 17 Major Watersheds

Hudson River Drainage Basin
1. Battenkill, Walloomsac, Hoosic

Lake Champlain Drainage Basin
2. Poultney, Mettowee
3. Otter, Little Otter, Lewis
4. Lower Lake Champlain
5. Upper Lake Champlain, LaPlatte, Malletts Bay, St. Albans Bay, Rock, Pike
6. Missisquoi
7. Lamoille
8. Winooski

Connecticut River Drainage Basin
9. White
10. Ottauquechee, Black
11. West, Williams, Saxtons
12. Deerfield
13. Lower Connecticut, Mill Brook
14. Stevens, Wells, Waits, Ompompanoosuc
15. Passumpsic
16. Upper Connecticut, Nulhegan, Willard Stream, Paul Stream

Lake Memphremagog Drainage Basin
17. Lake Memphremagog, Black, Barton, Clyde, Coaticook



Finding information on the watershed

There are many resources available for watershed research including maps, hydrologic information, information on fish and aquatic plants, lake, wetland, river and stream data and past and current monitoring efforts and studies.

You will be able to obtain a lot of this information by contacting your local municipality, Natural Resource Conservation Districts, Regional Planning Commissions, lake and watershed associations, the Vermont Department of Fish and Wildlife, and the Vermont Water Quality Division. Your data user may also be a good source of information and may guide you to additional resources.

After you have collected and reviewed available background information, you may want to revisit your monitoring purpose and the original questions you wanted to answer. Ask yourself if the background information answered your question(s), or changed the question(s) you want to answer.

General maps

U.S. National Atlas Online
www.nationalatlas.gov

USGS National Map
www.nationalmap.usgs.gov

TopoZone
www.topozone.com

U.S. Maps Using Census Data
http://tiger.census.gov/cgi-bin/mapsurfer

Vermont Center for Geographic Information
www.vcgi.org

Biophysical Regions of Vermont
http://vmc.snr.uvm.edu/BullBd/bprpage.htm

Vermont watershed information and maps

Detailed Maps of Vermont's 17 Major Basins
www.vtwaterquality.org/htm/wq_education.htm

Lake Champlain Basin Atlas
www.lcbp.org/ATLAS/HTML/intro.htm

VTDEC Basin Planning/Assessment Information
www.vtwaterquality.org/planning/htm/pl_basins.htm

U.S. EPA Watershed Maps and Information
www.epa.gov/surf

U.S. EPA EnviroMapper for Water
www.epa.gov/waters/enviromapper/index.html

Geology information and maps

Vermont Environmental Geology Maps
www.anr.state.vt.us/dec/geo/envseriesinx.htm

Bedrock and Geological Cross-section Maps
www.anr.state.vt.us/dec/geo/mapsonlineinx.htm

Vermont soils information & maps

Vermont Natural Resources Conservation Service
www.vt.nrcs.usda.gov/Soils

Wetland Soils Information
www.anr.state.vt.us/dec/waterq/wetlands/htm/wl_id-hydricsoil.htm

Fish, wildlife and exotic/invasive plant information & maps

Vermont Sport Fish Information
www.vtfishandwildlife.com/fish_sportfish.cfm

Vermont Wildlife Management Area Maps
www.vtfishandwildlife.com/wma_maps.cfm

Vermont Wildlife Management Unit (Regional) Maps
www.vtfishandwildlife.com/wmu_maps.cfm

VTDEC Aquatic Nuisance Species Information
www.vtwaterquality.org/lakes/htm/ans/lp_ans-index.htm

Wetlands information & maps

VTDEC Wetlands Section
www.vtwaterquality.org/wetlands.htm

Lake Champlain Basin Wetlands Map
www.lcbp.org/ATLAS/PDFmaps/nat_wetland.pdf

River and stream information

VTDEC River Management Section
www.vtwaterquality.org/rivers.htm

VTDEC Biomonitoring and Aquatic Studies Section (BASS)
www.vtwaterquality.org/bass.htm

USGS Vermont Gauge (Flow) Stations
http://vt.water.usgs.gov

River Network
www.rivernetwork.org

Vermont River Conservancy
www.vermontriverconservancy.org

Lake and pond information & maps

VTDEC Lakes and Ponds Section
www.vtwaterquality.org/lakes.htm

Lake Water Quality Summary Reports
www.anr.state.vt.us/dec/waterq/cfm/lakerep/lakerep_select.cfm

Vermont Lake Maps/Depth Charts
www.vtwaterquality.org/lakes/htm/lp_depthcharts.htm

Lake Champlain Depth Chart
www.lcbp.org/ATLAS/PDFmaps/nat_depth.pdf

Information on past and current monitoring efforts and studies

U.S. EPA National Directory of Environmental Monitoring Programs
www.epa.gov/owow/monitoring/dir.html

Vermont Lay Monitoring Program
www.vtwaterquality.org/lakes/htm/lp_lmp.htm

Aquatic Nuisance Species Watchers Program
www.vtwaterquality.org/lakes/htm/ans/lp_ans-index.htm

VTDEC Biomonitoring and Aquatic Studies
www.vtwaterquality.org/bass.htm

Lake Champlain Basin Program Monitoring
www.lcbp.org/monitsum.htm

Vermont watershed & lake associations
www.vtwaterquality.org/lakes/docs/lp_watershedprograms.pdf

Lake Champlain Committee
www.lakechamplaincommittee.org

Bonnyvale Environmental Education Center
www.beec.org

Eco Info: Air, Water, Land, & Energy Monitoring in Burlington and Lake Champlain
www.burlingtonecoinfo.net

Vermont Monitoring Cooperative
http://vmc.snr.uvm.edu

UVM Watershed Alliance
www.uvm.edu/~watershd

Local Conservation Commissions
www.uvm.edu/~envprog/epic/nbavcc.html

New England Regional Monitoring Collaborative
www.umass.edu/tei/mwwp/nermc

Lake Champlain Maritime Museum
www.lcmm.org

Vermont Public Interest Research Group
www.vpirg.org

Selecting appropriate parameters

Your monitoring program may collect information on the physical, chemical or biological condition of the waterbody. It is not essential to monitor all three conditions, but looking at them together will provide the most insight into water quality as they are interrelated and information on one condition can help explain the results of monitoring another.

Selecting what parameters you will monitor is directly related to "why" you are monitoring. For example, if you are monitoring a stream to determine the effects of a nearby sewage treatment plant on water quality, your parameters might include dissolved oxygen, turbidity, *E. coli*, pH, temperature and changes in the macroinvertebrate community, as these can indicate sewage pollution. Use Tables 3-1 and 3-2 as guidance for selecting parameters that will support your "why" question.

Table 3-1: Land Uses Contributing to Pollution and Associated Parameters for Volunteers to Consider Monitoring

Land Use (Source)	Associated Parameters to Monitor
Urban runoff	Turbidity, nutrients (phosphorus, nitrogen), temperature, conductivity, dissolved oxygen, biological survey (fish, plants, macroinvertebrates), pH, flow, optical brighteners, *E. coli*, streambank stability, geomorphic assessment
Construction/Development	Turbidity, temperature, dissolved oxygen, total suspended solids, biological survey, nutrients, pH, geomorphic assessment
Forestry	Turbidity, temperature, total suspended solids, nutrients, biological survey, pH, geomorphic assessment
Septic system/Sewage treatment plant	*E. coli*, nutrients, dissolved oxygen, conductivity, temperature, turbidity, pH, biological survey, optical brighteners
Farming/Agriculture	Turbidity, nutrients, temperature, total suspended solids, biological survey, *E.* coli, streambank stability, geomorphic assessment
Municipal and Industrial discharges	Temperature, conductivity, total suspended solids, pH, biological survey
Shoreline alteration	Turbidity, temperature, total suspended solids, biological survey, nutrients, riparian habitat assessment, geomorphic assessment, streambank or lakeshore stability

Physical parameters

Physical monitoring involves surveying and recording the waterbody's physical features. It may be qualitative (presence or absence of certain features) or quantitative (collecting measurements). Measuring physical parameters tends to be a cost-effective way to collect sound information on the condition of terrestrial and aquatic habitat, the general health of the waterbody and actions that can better protect the water quality.

Temperature

The rates at which biological and chemical processes progress depend on temperature. Aquatic organisms, from microbes to fish, are dependent on certain temperature ranges for their optimum health. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die.

Measuring temperature in lakes is also important for characterizing thermal stratification. Thermal stratification occurs when water at different temperatures becomes layered. It is important because it affects vertical mixing and the distribution of chemical and biological characteristics. For example, once a lake stratifies during the summer, no dissolved oxygen can be added into the lower lake layers and the oxygen that is there may become depleted. This causes stress to animals that need more oxygen and lower temperatures to survive.

Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C). It can be measured with either a thermometer or a meter, but it must be measured in the field.

Transparency and turbidity

Transparency is the depth to which light penetrates the water column. Turbidity is a measure of light scattering properties of suspended materials. In theory, the more suspended material that exists, the more light scattering (turbid), and hence the less transparent. A Secchi disk and turbidity meter are commonly used to measure these parameters.

Secchi transparency is a measurement of water clarity, and is considered an indirect measurement of algae or suspended sediment in the

Table 3-2: Water Quality Problems and Associated Parameters for Volunteers to Consider Monitoring

Problem/concern	Waterbody type	Associated parameters to monitor
Eutrophication (nutrient enrichment)	Lakes and streams	Nutrients (phosphorus, nitrogen), Secchi transparency (lakes), turbidity/transparency (streams), chlorophyll-*a*, dissolved oxygen, temperature, flow (streams), changes in the biological community
Habitat loss	Lakes, streams and wetlands	Macroinvertebrate surveys, habitat assessment, temperature, aquatic plant survey, wetland plants, amphibians (wetlands)
Low oxygen levels	Lakes and streams	Dissolved oxygen (profiles in lakes), nutrients, temperature, chlorophyll-*a*, flow, macroinvertebrate survey (streams)
Sedimentation	Streams and wetlands	Total suspended solids, turbidity/transparency, habitat assessment, macroinvertebrate survey, flow, precipitation
Erosion	Lakes and streams	Total suspended solids, turbidity/transparency, geomorphic assessment, precipitation
Algae	Lakes	Chlorophyll-*a*, nutrients, Secchi transparency, cyanotoxins or cyanobacteria
Exotic/invasive species	Lakes, streams and wetlands	Changes in the biological community, plant survey, habitat assessment

water. As one of three core measures used to characterize the trophic state of a lake (others are chlorophyll-*a* and total phosphorus), it is essential to any lake monitoring program. Determining a lake's trophic state will be described in detail in *Section 7*.

Secchi transparency is measured using a Secchi disk, a circular metal plate eight inches in diameter with black and white painted quadrants. The disk is attached to a rope marked in meters and lowered into the water until it disappears and then raised until it reappears, at which point that depth is recorded (in meters) as the transparency reading. It is probably the oldest, most affordable and easiest to use tool in lake water quality monitoring.

Turbidity can be measured in the field using a turbidity meter (nephelometer) or samples can be sent to a laboratory for analysis. Turbidity data can reveal problems with water clarity and/or suspended sediment in streams and rivers. Turbidity is reported in Nephelometric Turbidity Units (NTU).

Solids (TSS)

A variety of measurements provide information on the amount of dissolved and suspended material in surface water. Suspended materials influence the transparency, temperature, color and overall health of an aquatic ecosystem. TSS measurement cannot be done in the field. TSS is an important parameter to consider if you suspect sediment and water clarity issues. The total suspended solids (TSS) parameter is measured in milligrams per liter (mg/L), the mass of solids per unit volume of water.

Flow

Stream flow, or discharge, is the volume of water that moves past a specific point per unit of time. It is usually expressed as cubic feet per second (cfs or ft^3/sec). Flow is a function of water volume and the speed at which it is traveling (velocity). It is important because it has an impact on water quality and the habitats of living organisms in the stream. Fast-moving streams have higher dissolved oxygen concentrations than slow moving streams because they are more turbulent and better aerated. High flows can dilute dissolved pollutants, and at the same time, increase the amount of particulate pollutants such as silt and sediment suspended in the water, compared to low flows.

Flow in rivers and streams is dynamic, increasing in rainstorms, decreasing during dry periods, and changing with the seasons of the year. Since it is so dynamic, flow influences many of the water quality parameters likely to be monitored, as well as living organisms. Flow data are also necessary to use with sample concentration results in order to calculate the "load" of a substance delivered by a stream to a lake (i.e., pounds per year of phosphorus).

Getting Data on Flow

USGS Gauge Stations in Vermont

Flow is a critical part of stream and river monitoring efforts. You may be able to take advantage of existing flow stations or get assistance from professionals to develop a stage discharge curve, which relates the various stages (heights) of the stream to discharge (flow). For example, the USGS operates a gauge station on the Lamoille River in Johnson (USGS Station 04292000). If you were monitoring at or near this station, you could go to the river and read the river stage off the station's staff gauge, or go to the USGS website http://vt.water.usgs.gov/WaterData/station_map.htm, click on the Lamoille River station and see what the flow is right before or after you monitor.

Once you have an established stage discharge relationship, you only need to record the stage or elevation reading off a post in the river or on a bridge, to get an estimate of flow.

Some monitoring groups rely on qualitative estimates of flow (i.e., "high," "normal," or "low") to provide a general idea of stream conditions. Other groups measure flow using relatively sophisticated equipment and methods. Keep in mind that flow data may already be available from a local, state, or federal agency for the stream you are sampling (see side box "Getting Data on Flow"). Because of the complexity of flow monitoring, if you decide to include quantitative (i.e., numeric, rather than descriptive) flow monitoring in your plan, it is a good idea to consult a professional to help with initial design. The level of effort (and detail) you put towards flow measurement will depend on the purpose of your monitoring and how you want your data to be used. Measuring stream flow is an essential part of any stream or river monitoring effort.

Lake level

Similar to flow monitoring for streams, lake level measurements provide information about the hydrologic conditions of a lake (i.e., if the lake is experiencing high or low water levels) and are used to determine the mean water level, which has regulatory significance in Vermont.

To monitor a lake level, measure from a fixed point above the water (e.g., a bridge abutment or dam outlet) down to the surface of the water. If there is no fixed structure over the water, another option is to mark a fixed point on a shoreline tree or structure and use a hand level to take measurements. Once the hand level is at equal height with your mark, measure the distance from the hand level down to the surface of the water. Measurements should be taken periodically (often weekly) and after major rainstorm events.

The mean water level of a lake is the average of measurements taken between June 1 and September 15, as determined by the VTDEC. Water level information can help volunteers and water resource managers interpret other monitoring data, model lake water quality characteristics and understand the natural fluctuations of the lake. Before undertaking any lake level monitoring, contact the Water Quality Division at (802) 241-3777 to see if Division staff are monitoring the lake level at that waterbody, if a fixed measurement point has already been established and the location of that fixed point, so that measurements will be consistent.

Habitat

The type and quality of habitat in streams, rivers lakes and wetlands have a significant influence on living organisms. Some organisms prefer fast-moving water, others prefer quiet pools. Where degraded, poor habitat conditions may impair aquatic communities and frequently will be a greater stressor to the aquatic community than pollutants measured by chemical monitoring. Habitat assessments are an essential part of studies of the health of aquatic life in lakes, streams and rivers. You can assess habitat in several ways, ranging from visual observations recorded during stream walks or boating along the lakeshore to detailed measurements compiled into numerical indices.

Geomorphic assessment

A stream geomorphic assessment provides insight into the physical condition of a river, what stressors exist within its watershed and how those stressors have affected the physical processes of the river. This type of monitoring will require looking at maps, aerial photos, and historic information in combination with field observations to piece together the story of a stream's response to the natural and human disturbances that have occurred over time.

- For more information on geomorphic assessment, visit **www.vtwaterquality.org/rivers/htm/rv_geoassess.htm**.

Precipitation

Volunteers often collect precipitation (rainfall) data along with other parameters. Precipitation monitoring provides information that is critical to properly interpret other water quality data. For example, if you find unusually high sediment concentrations in a stream one day, knowing that it rained two inches the night before would provide helpful clues as to the reason for the excess sediment.

Precipitation monitoring can be done with a simple rain gauge placed in your yard or on your deck if your house is close to your monitoring site(s), or you may be able to rely on other volunteers to monitor precipitation if they live near the monitoring site(s). More complex monitoring may be done through the use of an automatic weather station installed at the sampling site.

Chemical parameters

Chemical indicators of water quality offer a snapshot of the water conditions. A program that monitors any or all of the following parameters over time (i.e., ten years) can help establish baselines and identify trends or any dramatic changes in water quality. Each of these chemical parameters can be used singly or in combination to answer specific questions about the waterbody.

Nitrates

Nitrogen is an essential plant and animal nutrient that naturally occurs in numerous forms in surface water. The forms most commonly measured are NO_3, NH_3, TN and (nitrate, ammonia and total nitrogen). High concentrations of any form of nitrogen in a waterbody may indicate that pollutants from animal manure, sewage, or fertilizers applied to land are making their way into the water via runoff.

Nitrate is the form of nitrogen that is readily used by plants and animals and comes from the sources listed above as well as through atmospheric deposition. High concentrations of nitrate may indicate the likelihood of an algae bloom, or cause changes in the plant and animal community. In some cases, ammonia-N is also important to measure because at elevated levels, in the un-ionized form, it is toxic to aquatic life. Total nitrogen measures all forms on nitrogen and reveals the potential of available nitrogen for plant and animal growth.

The different forms of nitrogen can be measured in a laboratory or with a field meter or kit. All forms are measured in milligrams per liter (mg/L).

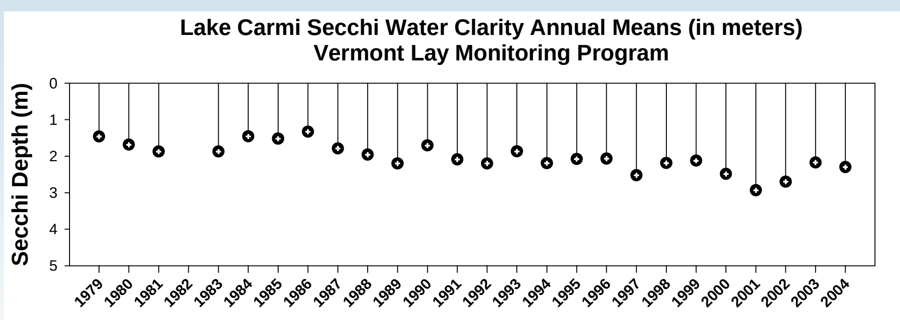
Phosphorus

Phosphorus is also an essential plant and animal nutrient and is the nutrient of greatest concern in eutrophication (nutrient enrichment). It is in most cases the "limiting nutrient," meaning it is the one most likely to restrict plant growth because of its naturally low levels in the environment. Thus, even small increases in phosphorus loads to a waterbody can cause large algal blooms and excessive plant growth. This rapid increase in biological activity may disrupt the ecological balance of surface waters.

Similar to nitrogen, numerous forms of phosphorus can be measured in a laboratory. The most common form is total phosphorus, which represents dissolved phosphorus and phosphorus attached to particles (i.e., soil) in the water. It is the single most important nutrient analysis to complete for a lake.

Documenting Water Quality Improvement

Since the late 1980s, conservation districts in the Lake Carmi watershed (Franklin, Vermont) have encouraged and supported farmers in efforts to reduce the amount of sediment and phosphorus entering the lake and its tributaries. Measures taken have included building concrete holding pits for manure and installing gutters on barn roofs to direct runoff away from barnyards.



The 26-year dataset accumulated by volunteer monitors participating in the Vermont Department of Environmental Conservation's Lay Monitoring Program is making it possible to document the beneficial effects of these agricultural practices. While changes are not always noticeable year to year, over time lake conditions have improved. Concentrations of both chlorophyll-*a* (a measure of the amount of algae) and phosphorus have shown statistically significant decreases, and the annual mean (average) Secchi transparency has nearly doubled, from 1.4 meters in 1984 to 2.3 meters in 2004.

Another form of phosphorus to consider monitoring is ortho-phosphorus, which represents the reactive phosphorus in the water. It is a measure of the phosphorus that is readily available for use by algae, and is important to consider in comprehensive lake and watershed studies. The nutrient phosphorus can be an indicator of sewage, animal manure, fertilizer, soil erosion problems and other types of contamination. Phosphorus is measured in milligrams or micrograms per liter (mg/L or µg/L).

Chlorophyll

Chlorophyll is the green plant pigment necessary for photosynthesis. It is used as an indicator of algae (phytoplankton) biomass in water. If algae populations are dense, water becomes noticeably green (or blue-green) with a lower than normal transparency and greater chlorophyll concentration. Under these conditions, water may not be suitable for swimming.

Chlorophyll is measured as chlorophyll-*a*, corrected for helophytic-*a*, a common degradation product of chlorophyll-*a* that can interfere with the chlorophyll-*a* measurement. Chlorophyll-*a* concentration is analyzed using fluorometric determination in milligrams or micrograms per liter (mg/L or µg/L).

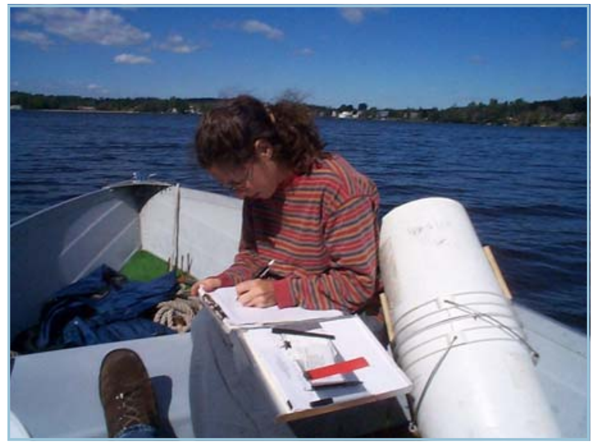
Chloride

Chloride is an ion that is released into surface waters through the breakdown of salt compounds. Although salt is a naturally occurring mineral, elevated levels in surface waters may be attributed to winter road maintenance practices and to human activities that accelerate erosion.

In addition to negatively impacting water quality, chloride in large concentrations can be corrosive; cause damage to vegetation; and enter the drinking water supply, causing discoloration, foul taste and odor. Chloride can be measured using a field kit or in a laboratory. It is measured in milligrams per liter (mg/L).

Conductivity

Conductivity estimates the amount of dissolved ions in the water. Conductivity is influenced by the size of the watershed and the geology. For example, a river or lake in a large watershed with limestone will have a higher conductivity because of the dissolution of carbonate minerals



carried into the waterbody from throughout the basin. The bigger the watershed size, the more water draining into a river or lake and the more contact with rock/soil before reaching the waterbody.

There are a number of pollution sources that may be signaled by increased conductivity. Wastewater from sewage treatment plants and septic systems, urban runoff from roads and agricultural runoff can all contribute to increased conductivity within a waterbody. The influence of road salt can be particularly episodic in nature with pulsed inputs when it rains or during snowmelt events. Agricultural runoff typically has high levels of dissolved ions.

Conductivity must be measured in the field with a field meter since it can be affected by environmental conditions, specifically temperature. Therefore, conductivity is reported as conductivity at 25 degrees Celsius and measured in microSiemens per centimeter (µS/cm).

Dissolved oxygen

Water contains oxygen in the form of a dissolved gas, which most aquatic organisms use to breathe. Dissolved oxygen (DO) is the measure of the concentration of the gas dissolved in water. All aquatic organisms have an optimal range of DO for functioning. Some require very high levels in order to flourish, and at low DO concentrations, sensitive animals may move away, weaken, or die.

Levels of DO can also influence decomposition rates and the composition and cycling of other water quality parameters. Low DO concentrations indicate either high demand for oxygen or limited re-aeration from the atmosphere. Low DO levels may indicate pollution, although low

DO in lakes can be a natural occurrence. Dissolved oxygen can be measured with a field meter or in a laboratory. Dissolved oxygen is reported as milligrams per liter (mg/L).

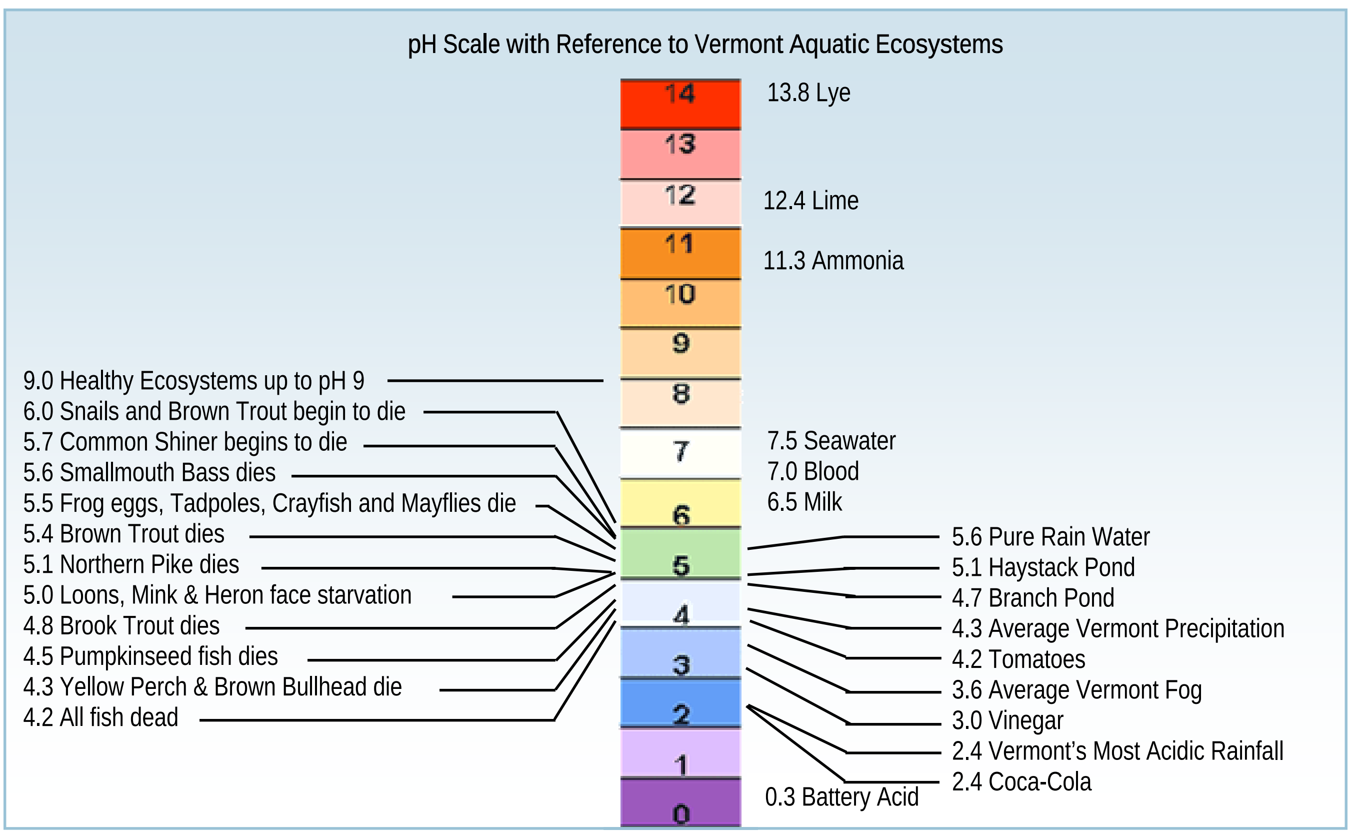
pH

pH is a measure of the hydrogen ion concentration, or acidity of water. It is measured on a scale from 0 to 14 pH (or standard) units, with 0 being the most acidic and 14 the most alkaline. A desirable range for surface water pH is between 6.5 and 8.5. The pH is not an indicator of a particular pollutant; however, it affects many chemical and biological processes in water. For example, low pH can allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. A pH between 5.0 and 6.0 causes the death of snails, trout, bass, pike, frogs, crayfish and mayflies, which in turn causes animals that feed on these lake-dwelling organisms to starve. If the pH falls to 4.2, all the fish and most other aquatic organisms would die.

The pH can be measured with paper strips, a field kit or a calibrated meter in the field. Most of the highly acidic lakes in Vermont are located at high elevations in the southern Green Mountains due to underlying bedrock and proximity to atmospheric pollution sources.

Alkalinity

Alkalinity is a measure of the buffering (or acid neutralizing) capacity of the water. Alkalinity is not a pollutant itself, but a measure of sensitivity to acid rain. The sensitivity of a lake to acid rain depends largely on the bedrock in the area. For



example, in a lake with limestone bedrock, the limestone dissolves in water, releasing ions (charged particles, such as calcium) that neutralize acid. A lake in an area with granite bedrock will not contain those ions to neutralize acid, predisposing it to acidification.

In Vermont, lakes most sensitive to acid rain are located in remote and undeveloped regions of the Green Mountains and pockets of the Northeast Kingdom. These lakes are generally small, at high elevation and located in areas with low buffering bedrock (granite).

Alkalinity is typically measured in a lab and reported as total alkalinity, which is determined and reported as the amount of calcium carbonate per liter (mg $CaCO_3$/L). Acid rain impacts may be a concern for lakes with alkalinities between 5.0 and 2.5 milligrams per liter. Lakes with alkalinities consistently less than 2.5 mg/L are considered chronically acidic and may be added to the state's Impaired Waters (303(d)) List.

- For more information on pH, alkalinity and acid rain, visit **www.vtwaterquality.org/bass/htm/bs_acidrain.htm**.

Optical brighteners

Optical brightener sampling devices can be used to help identify pollution from faulty septic systems, sewage leaks, storm drain cross-connections, and human/animal waste differentiation. Optical brighteners are fluorescent white dyes that are added to almost all laundry soaps and detergents to give clothes a clean, bright appearance. Optical brightener dyes are generally found in domestic wastewaters that contain laundry effluent. Therefore, optical brighteners can enter groundwater as a result of ineffective sewage treatment.

The optical brightener sampling device is relatively simple and inexpensive: untreated cotton pads inserted into a rigid sampling device that will hold the pad securely in place while allowing water to pass through it. These devices are usually placed in storm drains or pipe outlets.

Once removed from the pipe or drain, the cotton pads are viewed in a dark room under ultraviolet fluorescent lights. If optical brightener dyes are present, the pad will glow under the light.

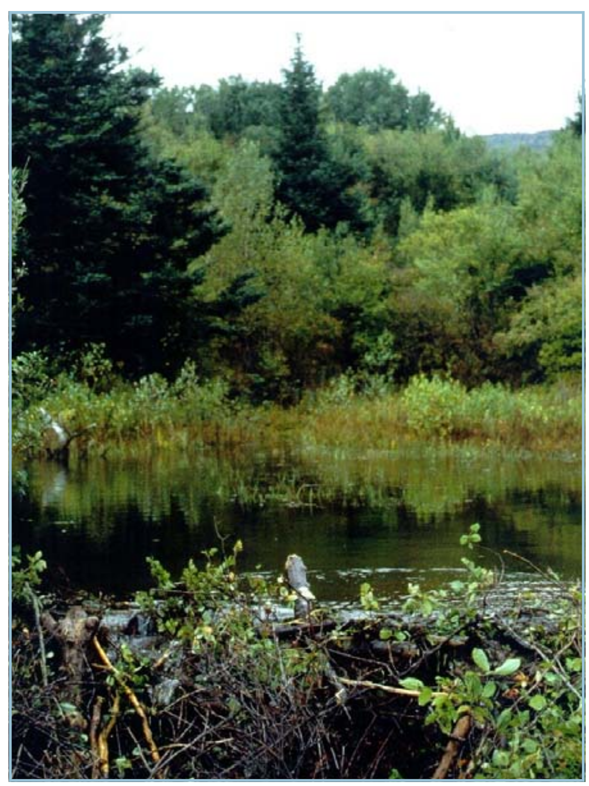
Biological parameters

Monitoring biological (living) parameters can help to determine water quality problems because:

- Biological communities reflect overall ecological integrity (i.e., chemical, physical and biological integrity).
- Biological communities change in response to a wide variety of pollutants and to the cumulative impacts of those pollutants.
- Routine monitoring of biological communities can be relatively inexpensive when compared to the cost of assessing chemical pollutants.
- The status of biological communities is of direct interest to the public as a measure of a pollution-free environment.
- Where nonpoint source impacts are degrading habitat, negative changes in the biological communities may be the only practical means of evaluation.

Flora (plants)

If you are monitoring a lake, you may want to include an aquatic plant survey in your program



since conditions such as water clarity, water chemistry, the shape and depth of the lake, and bottom sediment composition can influence the type and amount of plants in a lake. For example, increased nutrient loading from the watershed may spur some plants to more abundant growth, while harming other plants. The VTDEC also encourages aquatic plant monitoring for early detection of the presence of exotic/invasive species, which can disrupt a lake ecosystem in a very short amount of time.

- For more information on the VTDEC's Aquatic Nuisance Species Watchers Program contact the Vermont Water Quality Division at (802) 241-3777.

For wetland monitoring, it is particularly important to identify plants and plant communities. One of three characteristics that define a wetland is the presence of hydrophytic (water-loving) vegetation, which varies depending on the type of wetland. The absence of indicator plants in a wetland, where they would be expected, the presence of exotic/invasive species, or dominance by a single species could indicate stresses or pollution problems.

There is currently work underway in Vermont by the New England Interstate Water Pollution Control Commission (NEIWPCC) to develop protocols (the *Image-based Plant Estimate Protocol*) for volunteers to conduct wetland plant surveys that will generate data useful in characterizing a wetland's condition. Plants can be identified using simple methods such as noting the presence or absence of species, or with more complex surveys that map out species for the entire area or at representative plots/transects.

The VTDEC does not currently accept volunteer data for wetland assessments, but the Department's Purple Loosestrife Biological Control Program works with volunteers to raise and release beetles, conduct vegetation surveys, count beetle populations and hand pull or cut the invasive plants.

Monitoring Aquatic Invasive Species

The plants shown here are non-native aquatic invasive species that have the potential to wreak havoc on aquatic ecosystems. Once established, these plants grow and multiply quickly, choke out native species, negatively impact water quality, and can form dense tangled mats that can ruin recreational and aesthetic enjoyment of lakes and ponds. There is no known way to eradicate an established population, and simply controlling them costs millions of dollars annually. Water chestnut and Eurasian watermilfoil are already causing problems in Vermont waters and fanwort, hydrilla and Brazilian elodea are known to exist in neighboring states. For more information, fact sheets and watch cards, contact the Water Quality Division at (802) 241-3777.

Water chestnut

Fanwort

Brazilian elodea

Eurasian watermilfoil

Hydrilla

- For more information on the Purple Loosestrife Biological Control Program, contact the Vermont Water Quality Division Wetlands Section at (802) 241-3770.

- For more information on wetland volunteer monitoring, contact NEIWPCC at (978) 323-7929 or visit **www.neiwpcc.org**.

Amphibians

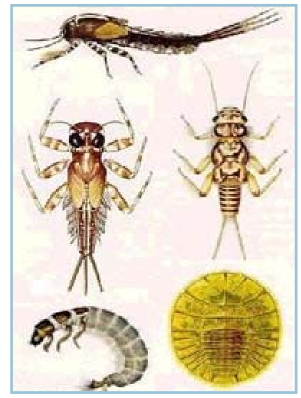
Identifying and counting amphibians is an important part of vernal pool (a type of temporary wetland formed from spring snowmelt) monitoring. Vernal pools are the breeding grounds for a variety of amphibians, so monitoring can help to ensure healthy and prolific populations. Amphibian monitoring activities can range from counting and identifying salamanders to listening and recording frog calls.

Bacteria (*E. coli)*

Fecal bacteria are a particular group of bacteria primarily found in human and animal intestines and wastes. *Escherichia coli* (*E. coli*) is one of the fecal coliform bacteria widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) organisms. When *E. coli* is found in waters, its presence is not the problem of concern itself but is used rather as an indicator of fecal contamination (most strains of *E. coli* are not pathogenic).

E. coli monitoring is commonly conducted to ensure that the water is safe for swimmers; to establish a relationship between rainfall, bird migration or other wildlife activity and *E. coli* levels; and to identify pollution sources (e.g., septic system failure, failing manure pit) in a watershed. You will need sterile equipment to sample for *E. coli* and make plans to have it analyzed within eight hours of collection. The bacteria is measured in organisms or colony-forming units per 100 milliliters of water (cfu/100 mL).

Macroinvertebrates



Macroinvertebrates are organisms that are large (macro) enough to be seen with the naked eye and lack a backbone (invertebrate). Macroinvertebrates are very sensitive to changes in the physical and chemical nature of their habitat. Therefore the composition of the aquatic animals serves as an excellent indicator of the overall environmental quality of a river or stream. They are most often part of school group monitoring, education programs and stream water quality assessments.

The VTDEC's Biomonitoring and Aquatic Studies Section (BASS) collects macroinvertebrate samples from streams throughout the state on a five-year rotational schedule to assess biological integrity and categorize the supported uses of the water. Volunteer data are not included in these assessments, as VTDEC protocols require species-level identifications, which require significant expertise generally beyond the scope of most volunteer monitoring programs.

Benthic (bottom-dwelling) macroinvertebrates inhabit all types of waters, from clear, fast-flowing streams with rocky bottoms to slow-moving, meandering rivers with sand and mud bottoms to wetlands. Examples include aquatic insects such as stoneflies, mayflies and caddis flies, as well as crayfish, snails, clams and worms.

- For more information on the VTDEC's BASS macroinvertebrate monitoring, visit **www.vtwaterquality.org/bass.htm**.

For volunteer groups, benthic macroinvertebrate monitoring is an ideal way to develop a deeper understanding of stream and river ecology and how human activities affect them for a number of reasons:

- They reflect the physical, chemical, and biological conditions of the stream.
- They have limited mobility and most cannot escape pollution, so they will show the effects of short- and long-term pollution events.
- They display a wide range of sensitivities to many forms of impairment and reflect cumulative impacts of pollution.
- They will reflect impacts from habitat loss.
- Some are very intolerant of pollution.
- They are relatively easy to sample and identify to a level that provides meaningful information about stream and wetland health.

The basic principle behind the use of macroinvertebrates in monitoring is that some are more sensitive to disturbance than others. Therefore, if a site is dominated by a group of organisms that are tolerant of human disturbance and the less tolerant organisms are missing, problems are likely.

The advantage of a macroinvertebrate biosurvey is that it tells us when the ecosystem is being affected by pollution or habitat loss. It is not difficult to realize that a stream full of many kinds of crawling and swimming "critters" is healthier than one without much life. It is easier to assess aquatic community health when macroinvertebrate data are combined with information about other biological assemblages (e.g., fish, algae or plants), and monitoring of physical and chemical information (e.g., habitat or dissolved oxygen).

It may also be helpful to combine macroinvertebrate data with chemical and physical parameters (including land uses) from upstream locations.

Now that you have finished reading *Section 3*, return to the Worksheet on pages 5-8 to answer the corresponding questions.

Macroinvertebrate Sampling Permit Requirements

In some cases, you may need to obtain a permit from the Vermont Department of Fish and Wildlife in order to sample macroinvertebrates in streams where there are known populations of threatened or endangered mussels. Some of these locations include:

- West River (Londonderry to Dummerston)
- Connecticut River (Guildhall, Lunenburg, and Hartford to Rockingham)
- Winooski River and Kingsbury Branch (southern Marshfield to East Montpelier)
- Moose River (St. Johnsbury, Concord, Victory)
- Nulhegan River (Ferdinand)
- Lewis Creek (Monkton, Hinesburg).
- From Lake Champlain to the first major falls of these tributaries:
  - Winooski River (up to Winooski One dam)
  - Lamoille River (up to Arrowhead Mountain Lake)
  - Missisquoi River (up to Highgate dam)
  - Hungerford Brook (Highgate)
  - Otter Creek (up to Vergennes dam)
  - Lewis Creek (up to Scott Pond)
  - Dead Creek (Panton, Addison)
  - Poultney River (up to Carvers Falls).

Photo submitted by River Network

- For more information, contact the Vermont Department of Fish and Wildlife's Nongame and Natural Heritage Program at (802) 241-3700.