Chapter 2

PHYSICAL/CHEMICAL MONITORING

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Physical/Chemical testing allows information to be gathered about **specific water quality characteristics**. A variety of water quality tests can be run on fresh water – including temperature, dissolved oxygen, pH, settleable solids, water clarity, phosphorus, nitrogen, chlorine, total dissolved solids, fecal coliform and many others. In addition to basic visual observations and weather information, Adopt-A-Stream recommends monitoring these core parameters:

- Temperature
- pH
- Dissolved Oxygen
- Conductivity (Stream and Lake)
- Salinity (Coastal)
- Water Clarity (Coastal and Lake)

Phosphorus, nitrogen, alkalinity, and setteable solids monitoring may be added to your list as interest and equipment allows.

If you choose to conduct chemical testing as an activity, plan on sampling regularly – at least once a month at the same time and the same location. Regular monitoring helps ensure your information can be compared over time. Water quality and environmental conditions can change throughout the day, so monitoring at approximately the same time of day is important. Also, chemical testing during or immediately after a rain may produce very different results than during dry conditions. Therefore, it is very important to record weather conditions. If conditions are unsafe for any reason, including high water or slippery rocks, **DO NOT SAMPLE**.

Equipment List:

- Chemical testing kit for appropriate parameters & instructions
- Conductivity Meter & Calibration Solution (Stream and Lake monitoring)
- Refractometer & Calibration Solution/Distilled Water (Coastal monitoring)
- Secchi Disk (Lake and Coastal monitoring)
- Waste jug (old milk jug labeled as 'Waste' will work)
- Rubber gloves & safety glasses
- Physical/Chemical Data Form (found on the AAS website)
- Bucket with rope (if sampling from a bridge or in deeper water)
- Clear container or Whirl-pak® bag for the visual observations
- Pen/pencil
- Clipboard
- Trash bag to pick up litter
- The 'Who to Call List' (found on the AAS website)
- First Aid Kit
- Waders, boots, or old tennis shoes

A list of places to purchase equipment is located on the AAS website.

Detailed instructions for each chemical test are found on the Adopt-A-Stream website; however, a few recommendations are listed below.

1. Measure air and water temperature in the shade. Avoid direct sunlight.
2. Rinse glass tubes or containers twice with stream water before running a test.
3. Collect water for tests in a well-mixed area of flowing water, one foot below surface. If water is less than one foot deep, collect approximately one-third of the way below surface. Collect samples at stream base flow.
4. Read values on plastic titrators (small syringe with green plunger) on the liquid side of the disc around the plunger tip. If you are using a glass syringes, read values at the plungers tip.
5. For dissolved oxygen and pH, run two tests. If the tests are not within duplicate precision of each other, run another test to ensure accuracy.

Safety Notes: Read all instructions before you begin and note all precautions. Keep all equipment and chemicals out of the reach of small children. In the event of an accident or suspected poisoning, immediately call the Poison Control Center (listed on the inside cover of most telephone books). Avoid contact between chemicals and skin, eyes, nose, or mouth. Wear safety goggles or glasses and rubber gloves when handling chemicals. After use, tightly close all chemical containers. Be careful not to switch caps.

Why Are Physical/Chemical Tests Important?

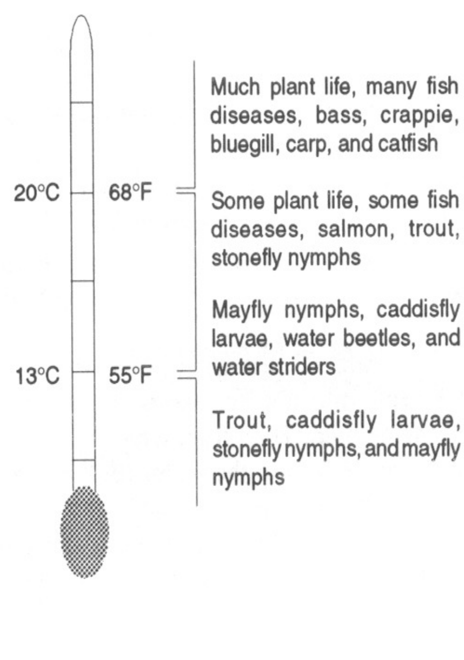
This section describes some chemical and physical tests you can conduct and why they are important. Physical/Chemical testing should be conducted at least once a month because this type of monitoring measures the exact sample of water taken, which can vary weekly, daily or even hourly. A shallow water monitoring kit (temperature, pH, and dissolved oxygen tests in waterproof monitoring case) and conductivity meter costs approximately $350 or approximately $200 to purchase these tests individually. Replacement chemicals are inexpensive and will need to be replaced as they expire or if they become contaminated. Additional parameters include total alkalinity, ortho-phosphate, conductivity, and nitrate. Some groups may wish to work with a certified laboratory to sample for chlorophyll A.

Further information for evaluating your test results can be found in the *Getting to Know Your Watershed* manual.

Temperature

Water temperature is one factor in determining which species may or may not be present in the system. Temperature affects feeding, respiration, and the metabolism of aquatic organisms. A week or two of high temperatures may make a stream unsuitable for sensitive aquatic organisms, even though temperatures are within tolerable levels throughout the rest of the year. Not only do different species have different requirements, optimum habitat temperatures may change for each stage of life. Fish larvae and eggs usually have narrower temperature requirements than adult fish.

Measuring Temperature
A thermometer protected by a plastic or metal case should be used to measure temperature in the field. Temperature is recorded in degrees Celsius. First, measure air temperature by placing the dry thermometer in the shade until it stabilizes. Record the temperature of the air before measuring water temperature. To measure water temperature, submerge the thermometer in a sample of water large enough that it will not be affected by the temperature of the thermometer itself, or hold it directly in the stream.



State Standards
Water temperatures should be less than 32.2°C (90°F) to meet Georgia state standards.

Significant Levels
Temperature preferences among species vary widely, but all species can tolerate slow, seasonal changes better than rapid changes. Thermal stress and shock can occur when water temperatures change more than 1 to 2 degrees Celsius in 24 hours.

Many biological processes are affected by water temperature. Temperature differences between surface and bottom waters help produce the vertical water currents, which move nutrients and oxygen throughout the water column.

What Measured Levels May Indicate
Water temperature may be increased by discharges of water used for cooling purposes (by industrial or utility plants) or by runoff from heated surfaces such as roads, roofs and parking lots. Cold underground water sources, snow melt, and the shade provided by overhanging vegetation can lower water temperatures.

pH

The pH test is one of the most common analyses in water testing. An indication of the sample's acidity, pH is actually a measurement of the activity of hydrogen ions in the sample. pH measurements are on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids and those above 7.0 considered bases.

The pH scale is logarithmic, so every one-unit change in pH actually represents a ten-fold change in acidity. In other words, pH 6 is ten times more acidic than pH 7; pH 5 is one hundred times more acidic than pH 7.

Measuring pH
pH is measured by adding a reagent to a sample of water which dyes the sample based on its pH level. The color of the water sample is then matched to a color comparator to determine the pH level. Take two samples for duplicate precision. The two samples must be within ±0.25. If the tests are not within duplicate precision of each other, run another test until two are within that range.

State Standards
pH levels should fall between 6.0 and 8.5 to meet Georgia state standards.

Significant Levels
A range of pH 6.5 to pH 8.2 is optimal for most aquatic organisms. Rapidly growing algae or submerged aquatic vegetation remove carbon dioxide (CO_2) from the water during photosynthesis. This can result in a significant increase in pH levels, so the water becomes more basic. Low or high pH can affect egg hatching, kill sources of food for fish and insects, or make water uninhabitable for any aquatic life. In

Georgia, mountain and piedmont streams will have pH ranges of 6.0 to 8.0. Black water streams of coastal and south Georgia will naturally have more acidic conditions, with pH values as low as 3.5. In coastal waters, normal pH levels fall within state standards and increase (becomes more basic) with increasing salinity. In other regions of Georgia, pH readings outside of the acceptable levels may be the result of mine drainage, atmospheric deposition or industrial point discharges.

pH values of some common substances:

pH	
0.5	battery acid
2.0	lemon juice
5.9	rainwater
7.0	distilled water
8.0	salt water
11.2	ammonia
12.9	bleach

Dissolved Oxygen (DO)

Like land organisms, aquatic animals need oxygen to live. Fish, invertebrates, plants, and aerobic bacteria all require oxygen for respiration. Dissolved oxygen is measured in parts per million (ppm) or milligrams per liter (mg/L).

Sources of Dissolved Oxygen

Oxygen dissolves readily into water from the atmosphere at the surface until the water is "saturated". Once dissolved in water, the oxygen diffuses very slowly, and distribution depends on the movement of aerated water by turbulence and currents caused by wind, water flow and thermal upwelling. Aquatic plants, algae and phytoplankton produce oxygen during photosynthesis.

Dissolved Oxygen Capacity of Water

The dissolved oxygen capacity of water is limited by the temperature and salinity of the water and by the atmospheric pressure, which corresponds with altitude. These factors determine the highest amount of oxygen that is able to dissolve in the water.

As water temperature changes, the highest potential dissolved oxygen level changes.

> Lower temperature = Higher potential dissolved oxygen level
> Higher temperature = Lower potential dissolved oxygen level

- At 0 degrees Celsius the saturation point for dissolved oxygen is 14.6 ppm
- At 32 degrees Celsius the saturation point for dissolved oxygen is 7.6 ppm

The temperature effect is compounded by the fact that living organisms increase their activity in warm water, requiring more oxygen to support their metabolisms. Critically low oxygen levels often occur during the warmer summer months when capacity decreases and oxygen demand increases. This is often caused by respiring algae or decaying organic material.

Measuring Dissolved Oxygen

Dissolved oxygen is measured using the Winkler titration method. A sample bottle is filled completely so that no air is present in the sample. Reagents are added to produce a 'fixed' solution – the dissolved oxygen content cannot be influenced by external sources or changes. This fixed solution is then titrated until it reaches the 'endpoint' where the color of the solution changes to clear. The level of the remaining liquid in the direct-read titrator corresponds to the dissolved oxygen level in the sample. Take two samples for duplicate precision. The two samples must be within ±0.6 ppm or mg/L. If the tests are not within duplicate precision of each other, run another test until two are within that range.

State Standards

Dissolved oxygen levels must average 5mg/L and no less than 4mg/L to meet Georgia state standards.

Significant Levels

The amount of oxygen required by an aquatic organism varies according to species and stage of life. DO levels below 3 ppm are stressful to most aquatic organisms. DO levels below 2 or 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for growth and activity. Fish and invertebrates that can move will leave areas with low dissolved oxygen and move to higher level areas.

What Measured Levels May Indicate

A low dissolved oxygen level indicates a demand on the oxygen in the system. Pollutants, including inadequately treated sewage or decaying natural organic material, can cause such a demand. Organic materials accumulate in bottom sediments and support microorganisms (including bacteria), which consume oxygen as they break down the materials. Some wastes and pollutants produce direct chemical demands on any oxygen in the water. In ponds or impoundments, dense populations of active fish can deplete dissolved oxygen levels. In areas of dense algae, DO levels may drop at night or during cloudy weather due to the net consumption of dissolved oxygen by aquatic plant respiration.

High dissolved oxygen levels can be found where stream turbulence or choppy conditions increase natural aeration by increasing the water surface area and trapping air under cascading water. On sunny days, high dissolved oxygen levels occur in areas of dense algae or submerged aquatic vegetation due to photosynthesis. In these areas, the lowest DO levels occur just before sunrise each morning and highest levels just after noon.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity levels indicate the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius. Conductivity is measured in microsiemens per centimeter (µs/cm).

Conductivity in natural systems is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock such as in north Georgia tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water.

Measuring Conductivity

Conductivity is measured with a parameter-specific probe that must be calibrated with a known conductivity standard within 24 hours prior to each monitoring event. A single measurement is recorded for conductivity.

State Standards

There are no regulated levels of conductivity in Georgia.

Significant Levels

Distilled water has conductivity in the range of 0.5 to 3 µs/cm. The conductivity of rivers in Georgia generally ranges from 0 to 1500 µs/cm. Studies of inland fresh waters indicate that streams supporting mixed fisheries have a range between 50 and 500 µs/cm. Some north Georgia streams may have natural background levels well below 50 µs/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can be as high as 10,000 µs/cm.

What Measured Levels May Indicate

Discharges to streams can change the conductivity depending on their composition. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity. Conductivity can also fluctuate from baseline levels because of mining operations, agriculture, and urban runoff. Documented changes in conductivity readings warrant further investigation.

Salinity

Salinity refers to the concentration of dissolved salts in seawater. More specifically, salinity is the number of grams of dissolved salts in a kilogram of seawater, thus the units of salinity are parts per thousand (ppt). The salinity of average ocean water is 35 ppt. Aquatic plants and organisms are sensitive to changes in salinity.

Coastal Conditions
Coastal and inshore waters such as estuaries, tidal rivers and marsh creeks generally have lower salinity values. These inshore areas also have highly variable salinity conditions. As the tide comes in or rises, seawater is pushed further inshore or inland, and the salinity at a particular location might increase within hours. Similarly, as the tide goes out, the seawater moves seaward and thus the salinity may decrease.

Salinity is a very important feature and parameter of coastal aquatic habitats. Not only does salinity affect the biological community, but it also affects the density of the water itself. The resulting water density has an effect on, and may be the cause of water flow and transport (both speed and even direction). In fact, typical inshore water circulation includes less dense, less salty water moving downstream along the surface while denser, saltier water is actually moving inshore/upstream along the bottom.

In coastal aquatic habitats, it is thus very important to know and record the salinity at any monitoring site. Salinity is one of the most basic chemical parameters for characterizing a coastal aquatic habitat.

Estuary Monitoring
Estuaries are partially enclosed bodies of water where seawater and freshwater (e.g. from a river) mix. With variations in river inflow (due to rainfall, melting, freshwater removal for industries, agriculture, etc.) and the constant tidal action moving seawater in and out, estuaries are water bodies of temporally and spatially variable salinity. Organisms that live in estuaries must be able to withstand variable salinity conditions. Adaptations include escaping/moving to more favorable conditions, closing up until more favorable conditions return, burrowing/digging into the bottom, using internal water balance metabolic processes such as producing more or less urine, drinking more or less water, or spending more energy to conserve or get rid of excess water and salts. Georgia estuarine animals such as oysters, blue crabs, shrimp, and mullet are capable of surviving in and dealing with the variable salinity conditions of coastal rivers, sounds, and salt marshes.

Measuring Conductivity
Salinity is most commonly determined by using a salinity refractometer, a hand held device that measures the refraction or bending of light passing through a solution to determine the strength or concentration of that solution. The refractometer should be calibrated within 24 hours prior to each monitoring event. Take two samples for duplicate precision. The two samples must be within ±1.0ppt. If the tests are not within duplicate precision of each other, run another test until two are within that range.

State Standards
There are no regulated levels of salinity in Georgia.

What Measures Measured Levels May Indicate
If high salinity readings are found in upstream rivers and estuaries, which traditionally have lower salinity readings, freshwater flow may be reduced. This in turn will impact the coastal aquatic habitat.

Water Clarity

Water clarity refers to the transparency or clearness of the water. It is affected by the amount of suspended particles in the water column and algae growth. Suspended particles can lower water clarity which can limit the amount of sunlight available for photosynthesis, damage the gills of fish and macroinvertebrates, suffocate fish and oysters, and disturb filter feeding organisms.

Measuring Water Clarity
The Secchi disk (pronounced sec'-key) is used to measure the clarity of the water. The disk is named after Pietro Angelo Secchi, a papal scientific adviser and head of the Roman Observatory in the 1860s. Secchi lowered a white plate on a rope into the Mediterranean to determine the depth at which he could no longer see it as a relative measure of water clarity.

Modern Secchi disks are weighted metal disks. The face of the disc is divided into quarters and painted black and white for contrast. The disk is lowered into the water to the point at which the disk can no longer be seen – this depth is then called the Secchi depth. Secchi depths can then be compared to track changes and compare differences in water clarity within and between bodies of water. Take two Secchi disk depth readings for duplicate precision. The two samples must be within ±10cm. If the tests are not within duplicate precision of each other, run another test until two are within that range.

State Standards
There are no regulated levels of water clarity or Secchi depth in Georgia.

What Measured Levels May Indicate
Water clarity can be affected by natural influences such as wind, rainfall, tidal stage, and algae growth. Human influences can cause changes in water clarity. Nutrient additions, development, boating or dredging activities could cause the clarity of a waterbody to decrease.

Settleable Solids

The settleable solids test is an easy, quantitative method to measure sediment and other particles found in surface water. A measurement of settleable solids is not the same as a turbidity reading. Turbidity levels are measured by taking into account all particles suspended in the water column, including small, colloidal sized particles, like clay. A settleable solids test only measures those particles large enough to settle out within a given period of time.

Excessive solids in water can block sunlight and clog fish and macroinvertebrate gills. Sediment that settles on the streambed can smother habitat for fish and other aquatic life. Sediment can also carry harmful substances such as bacteria, metals, and excess nutrients.

Measuring Settleable Solids

An Imhoff cone (a plastic or glass 1 liter cone) is filled with one liter of sample water, stirred, and allowed to settle for 45 minutes. Solids will settle in the bottom of the cone and are then measured as a volume of the total, in millimeters per liter. This measurement is a reproducible analogue for turbidity.

State Standards

There are no regulated levels of settleable solids in Georgia.

What Measured Levels May Indicate

Land-disturbing activities contribute to elevated levels of settleable solids in Georgia's streams, rivers, lakes and wetlands. Possible sources include cropland, pasture, livestock operations, forestry activities, construction, roads, and mining operations. Sediment in streams functions much like sandpaper, scouring stream banks, leading to streambank failure, and ultimately causing further erosion.

Nutrients

The addition of nitrogen, phosphorus and other nutrients to a body of water may lead to increased plant growth, ultimately resulting in algae blooms. Over time, living and dead plant material builds up and, combined with sediments, fills in lakes and reservoirs. This is a naturally occurring process called **eutrophication**. However, when excess nutrients and sediment are added as a result of human activity, the speed of this natural process is increased significantly.

> Eutrophic – a body of water with excess nutrients, sediment and organic matter, which often causes water quality problems.

Plants, especially algae, are very efficient users of nitrogen and phosphorus. By the time an algae bloom is observed, the nutrients may no longer be measurable but may continue to impact the ecosystem. By sampling upstream from areas of algae blooms, the source of excess nutrients may be identified. Algae blooms will usually be found in lakes and reservoirs. If excessive algae are found in streams, the nutrient content is probably very high. The macroinvertebrate population will reflect a high input of nutrients, meaning you may find little variety of macroinvertebrates but many of one or two kinds.

High flow rates in streams may prevent the establishment of floating aquatic plants and algae despite the presence of high levels of nutrients. As the summer progresses and flow rates drop, once rapidly flowing streams can become choked with algae. Wide, slow moving and tidal areas downstream may exhibit algae blooms weeks earlier.

Sources of Nutrients

Nitrogen and phosphorus enter water from human and animal waste, decomposing organic matter and fertilizer runoff. Phosphates are also found in some industrial effluents, detergent wastewater from homes, and natural deposits.

Nitrates

Nitrogen occurs in natural waters as ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), and organically bound nitrogen. Through a process called nitrification, bacteria convert ammonium to nitrites, which are quickly converted into nitrates. Ammonia test results are expressed as “ammonia as nitrogen”. Nitrate test results are expressed as "nitrate nitrogen" (NO_3-N), meaning "nitrogen that was in the form of nitrate." Some test kits and literature express levels only as nitrate (NO_3). Both expressions refer to the same chemical and concentrations, but use different units of measure:

Nitrate Nitrogen ppm x 4.4 = Nitrate ppm

Significant Levels

Unpolluted waters generally have a nitrate-nitrogen level below 1 ppm. Nitrate-nitrogen levels above 10 ppm (44 ppm nitrate) are considered unsafe for drinking water.

What Measured Levels May Indicate

Levels of nitrate-nitrogen above 1 ppm may indicate a sewage overflow. High levels may also indicate the presence of fertilizers and animal waste. High levels of ammonia nitrogen generally indicate a more immediate source of pollutants.

Phosphorus

Phosphorus occurs in natural waters in the form of phosphates, orthophosphates, polyphosphates and organically bound phosphates. Simple phosphate test kits measure reactive phosphorus (primarily orthophosphate), which is the form of phosphate applied as fertilizer to agricultural and residential lands.

Organically bound phosphates in water come from plant and animal matter and wastes. Organically bound phosphates and polyphosphates cannot be measured directly. They must first be broken down and then an orthophosphate test is performed to measure total phosphorus. Results are expressed as phosphate (PO_4).

Significant Levels

Total phosphorus levels higher than 0.03 ppm contribute to increased plant growth (eutrophic conditions), which will lead to oxygen depletion. Total phosphorus levels above 0.1 ppm may stimulate plant growth sufficiently to surpass natural eutrophication rates.

What Measured Levels May Indicate

Levels in excess of 0.1 ppm indicate a potential human source such as industrial soaps, sewage, fertilizers, disturbance of soil, animal waste, or industrial effluent.

Alkalinity

Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the bases found in a sample, including carbonate, bicarbonate, and hydroxide content. The alkalinity, and therefore buffering capacity, of natural waters will vary with local soils.

Significant Levels

The higher the alkalinity, the better the capacity to buffer the fluctuation of pH in water. To protect aquatic life it should be at least 20 mg/L.

What Measured Levels May Indicate

Alkalinity levels should not fluctuate much unless a severe industrial problem has occurred upstream.