Water Quality

Theme: Water Quality
Best Time to Plan Trip: Fall or Spring

Unit Rationale

The Smokies has over 2,100 miles of rushing mountain streams and rivers that flow through the park. In each mile lives a diverse community of native fish, amphibians, insects, and larvae, some of which are found only in the Southern Appalachians. Park fisheries managers and university researchers monitor water quality, fish populations, and watersheds to better understand the dynamics of water running through diverse ecosystems. During this unit the students will assist the park in collecting data from the stream and identify the quality of the stream using water quality test parameters and macroinvertebrate findings.

North Carolina Curriculum Correlations

Earth/Environmental Science Essential Standards

Essential Standard EEn.2.2 Understand how human influences impact the lithosphere
- EEn.2.2.1 Explain the consequences of human activities on the lithosphere past and present.
- EEn.2.2.2 Compare the various methods humans use to acquire traditional energy sources.

Essential Standard EEn.2.3 Explain the structure and processes within the hydrosphere
- EEn.2.3.2 Explain how ground water and surface water interact.

Essential Standard EEn.2.4 Evaluate how humans use water.
- EE.2.4.1 Evaluate human influences on freshwater availability.
- EE.2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.

Essential Standard EEn.2.7 Explain how the lithosphere, hydrosphere, and atmosphere individually and collectively affect the biosphere.
- EEn.2.7.2 Explain why biodiversity is important to the biosphere.
- EEn.2.7.3 Explain how human activities impact the biosphere.

Biology Essential Standards

Essential Standards Bio.2.1 Analyze the interdependence of living organisms within their environments
- Bio.2.1.1 Analyze the flow of energy and cycling of matter (such as water, carbon, nitrogen and oxygen) through ecosystems relating the significance of each to maintaining the health and sustainability of an ecosystem.

Essential Standards Bio.2.2 Understand the impact of human activities on the environment (one generation affects the next).
- Bio.2.2.1 Infer how human activities may impact the environment.
- Bio.2.2.2 Explain how the use, protection and conservation of natural resources by humans impact the environment from one generation to the next.

AP Biology Goals and Objectives

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.
- 1.01 The learner will identify questions and problems that can be answered through scientific investigations.
- 1.02 The learner will conduct scientific investigations to answer questions about the physical world.

1.03 The learner will formulate and revise scientific explanations and models using logic and evidence.

1.04 The learner will apply safety procedures in the laboratory and in field studies:

Competency Goal 6: The learner will develop an understanding of the unity and diversity of life.

6.05 The learner will examine the structure and function of plants and animals.

Competency Goal 7: The learner will develop an understanding of basic ecological principles.

7.01 The learner will analyze population dynamics.

7.02 The learner will examine the actions and interactions of communities and ecosystems.

7.03 The learner will assess current global issues.

AP Earth And Environmental Science (APES) Goals and Objectives

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.

1.01 The learner will identify questions and problems in the earth and environmental sciences that can be answered through scientific investigations.

1.02 The learner will conduct scientific investigations to answer questions related to earth and environmental science.

1.03 The learner will formulate and revise scientific explanations and models using logic and evidence.

1.04 The learner will apply safety procedures in the laboratory and in field studies.

Competency Goal 2: The learner will build an understanding of the interdependence of Earth's systems.

2.02 The learner will investigate the cycling of matter.

2.05 The learner will investigate the biosphere.

Competency Goal 4: The learner will build an understanding of the distribution, ownership, use and degradation of renewable and nonrenewable resources.

4.01 The learner will analyze sources and uses of freshwater and oceans.

4.04 The learner will analyze biological resources.

4.06 The learner will analyze land types and uses.

Competency Goal 5: The learner will build an understanding of air, water and soil quality.

5.01 The learner will analyze the sources of major pollutants.

5.02 The learner will investigate the effects of pollutants.

5.03 The learner will analyze and investigate pollution reduction, remediation and control measures.

5.05 The learner will analyze impacts on human health.

Competency Goal 7: The learner will build an understanding of environmental decision making.

7.03 The learner will recognize significance of major environmental laws and regulations: regional, national and international.

7.04 The learner will develop an awareness of environmental options.

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Planning a Successful Trip

Schedule for a day of activities in Great Smoky Mountains National Park at Purchase Knob

- Meet park ranger at Purchase Knob
- Use restrooms
- Large group introduction
- Break into two groups
- Participate in activities
- Lunch
- Switch groups
- Large group conclusion

•Check the weather before you go. Lunch will be eaten outside.

•School buses can park at the program site.

•The pre-visit activities included in this packet are specific to the theme of your program and should be presented prior to your scheduled visit. The post-visit activities are designed to reinforce and build upon the park experience.

• A map to the Appalachian Highlands Science Learning Center Purchase Knob can be found on page 7

• All students, teachers, and chaperones will meet the park rangers at the Appalachian Highlands Science Learning Center at Purchase Knob.

•The maximum number of students for this trip is 60. We require an adult or teacher for every ten students to create a positive and rewarding experience. The on-site instruction is conducted by a park ranger. However, your assistance is needed with discussion and discipline. Please feel free to contact the park at (828) 926-6251 if you have any further questions.

•Dressing for the Weather
Please remind your students to wear appropriate footwear and clothing for an extended outdoor program. Short pants, flip flops, or sandals are not recommended. Temperatures in the mountains can be 10-15 degrees colder than at your school. You may wish to alter portions of the program should inclement weather appear.

•Restrooms and Water
Restrooms and water fountains will be available at the program site.

• Lunch
Lunches will be eaten picnic style on the grounds of the Learning Center. Lunches should be put in a box for storage and kept on the bus until needed. Lunches, snacks, and drinks should be provided by the students. There are no concessions at Purchase Knob.

• Safety
Purchase Knob is a remote location, far from any medical facilities. Students will spend most of their time away from buildings, so please bring a cellular phone. Notify the park ranger of any special concerns or medical conditions including students with allergies, asthma or other medical conditions.

• Cancellation
Should anything unforeseen occur preventing you from keeping your appointment, please contact the park at (828) 926-6251 to notify us of your late arrival or cancellation.

Background Information

Park Description:

The National Park Service is charged with the management and preservation of the nation's most precious natural and cultural resources. These resources are woven into our natural heritage, and they provide opportunities for recreation, appreciation of beauty, historical reflection, cultural enrichment, and education.

Great Smoky Mountains National Park is one of the largest protected land areas east of the Rocky Mountains. With over 500,000 acres (800 square miles) of forest, the Smokies contain an enormous variety of plants and animals. In terms of biological diversity, a walk from a mountain's foot to its peak is comparable to the 2,000 mile hike on the Appalachian Trail from Georgia to Maine.

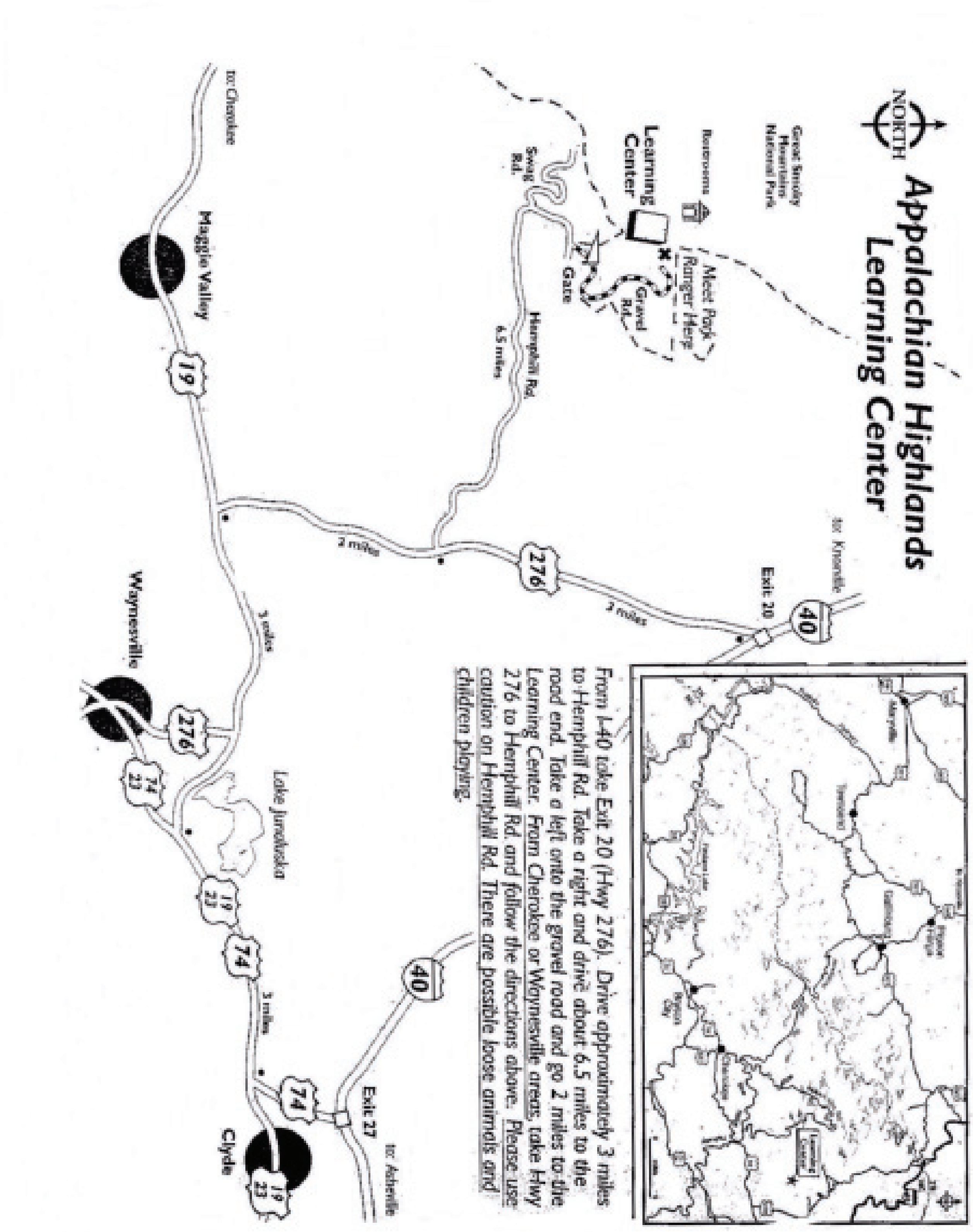
Because the National Park Service is charged with protecting resources and natural systems, the park engages in comprehensive research programs, such as air quality monitoring, to foster an understanding of park resources and to show how they are affected by local, regional, and global influences. Since the Smokies are so biologically diverse, the park is designated as an International Biosphere Reserve by the United Nations. The international system contains over 320 reserves in over 80 countries with the primary objectives of conserving genetic diversity and coordinating environmental education, research, and monitoring.

The Smokies also have a rich cultural history. Native Americans have lived in this area for thousands of years, and permanent white settlement began around 1800. The coming of commercial logging around 1900 stripped trees from two-thirds of what is now park land. Established in 1934, the park was created from more than 6,000 tracts of private and commercial land that was bought mostly with money raised and privately donated. Centrally located within a two-day's drive for half of the nation's population, Great Smoky Mountains National Park has the highest visitation of all the national parks in the country.

Purchase Knob Description:

The Purchase Knob property, over 530 acres in size, was donated to Great Smoky Mountains National Park by Katherine McNeil and Voit Gilmore in January 2001. Situated at an elevation of over 5,000 feet, the area contains old-growth forests, mountain meadows and high elevation wetlands. It also rests on geological formations that aren't found anywhere else in the park, lending to a unique and diverse habitat for the study of plants and animals. The house is the location of the Appalachian Highlands Science Learning Center, whose mission is to provide a space for researchers to perform biological inventory and monitoring while offering education programs for students and teachers on these same subjects.

MAP TO PURCHASE KNOB



Pre-Site Activity
Water Quality Information

Grade Level: High School

Subject Area: Science

Activity time: 60 minutes

Setting: Classroom

Skills: Analyzing, Categorizing, Communicating, Comparing, Describing, Listening

Vocabulary:

•**Acidic:** a solution that has more hydrogen ions than it does hydroxide ions.

•**Acid Neutralizing Capacity (ANC):** a measure of the ability of a water sample to neutralize strong acid; determined on a whole-water sample.

•**Alkalinity:** a measure of the ability of a water sample to resist a decrease in pH and thus protects humans, wildlife, and aquatic life from the effects of acidification.

•**Basic:** a solution that has more hydroxide ions than hydrogen ions.

•**Benthic:** bottom dwelling organisms living below the water surface on the substrate

•**Biomass:** the collective total mass of an organism, population, community or ecosystem.

•**Conductivity:** measure of how well a water sample conducts electricity and an estimate of the total dissolved solids in a sample.

•**Dissolved oxygen (DO)**: the concentration of free molecular oxygen (a gas) dissolved in water.

•**Ecosystem:** a hypothetical 'system' used to describe patterns in the various ways that living and non-living things interact.

•**Eutrophication**: a process by which water rich in mineral and organic nutrients promotes a proliferation of plant life which overproduces, dies, and eventually reduces water's oxygen level as bacteria decompose it (using more oxygen in the process).

•**Macroinvertebrate**: an invertebrate that is large enough to be seen without the use of a microscope.

•**Nitrogen fixation:** the conversion of elemental nitrogen in the atmosphere to a form that can be used as a nitrogen source by organisms.

•**Parameters:** measurable characteristics that may be used to explain biological systems (for example, acid rain deposition in a forest soil is a measurable parameter).

•**pH:** the hydrogen ion concentration of hydroxide ions when they are dissolved in water.

•**Predator:** an organism which primarily obtains energy from consuming other living non-plant organisms.

•**Species richness**: the total number of species collected in a sample or community.

•**Specific heat**: the amount of heat per unit mass required to raise the temperature of a material by one degree Celsius.

•**Tolerance**: generally used to refer to the ability of organisms to withstand pollution.

Objectives:

1) become familiar with the vocabulary associated with water quality monitoring
2) become familiar with the types of water quality tests within water quality monitoring
3) become familiar with the basics of a stream
4) understand the biodiversity of the Great Smoky Mountains National Park
5) recognize that many plants and animals in the park are endemic species, meaning they are known to live only in the park
6) become familiar with the current threats to the water systems within the Park.

Materials:

•Water Quality Vocabulary listed on left
•Stream Ecology Basics and Water quality parameters worksheet (pages 9-10)
•Computer with internet connection.

Background:

When students visit the Smokies on their field trip they will be collecting data as part of the Water Quality monitoring study. This lesson will introduce the basics of a stream and benthic macroinvertebrates, key vocabulary terms, and information regarding the different water quality tests that will be performed. Relate to the students that during their field trip to Purchase Knob they will be assisting in a research project by collecting data on the water quality of the Purchase Knob stream. To do this, they will need to be knowledgeable of the vocabulary used during the trip.

Procedure:

Students should work in pairs or by themselves in reviewing the different Parameter Tests, Stream Ecology Basics, and Vocabulary. All of the Parameter tests will be reviewed in the field but a early introduction to the tests is essential. Students will probably be familiar with most of the definitions but reviewing the list before the trip is important.

To view the Biodiversity podcast video go to **http://www.thegreatsmokymountains.org/eft/10modules.html** Turn the microscope knob that appears on the computer screen to Section 1, Understanding Biodiversity. Click "Watch Video" and view video.

To view the Spruce Fir podcast video go to **http://www.thegreatsmokymountains.org/eft/10modules.html** Turn the microscope knob that appears on the computer screen to Section 2, A Connected Web. Click "Watch Video" and view video.

To view the Linking Geology and Life podcast video go to **http://www.thegreatsmokymountains.org/eft/10modules.html** Turn the microscope knob that appears on the computer screen to Section 3, Why So Diverse Here? Click "Watch Video" and view video.

To view the Hellbenders podcast video go to **http://www.thegreatsmokymountains.org/eft/10modules.html** Turn the microscope knob that appears on the computer screen to Section 4, Studying Biodiversity. Click "Watch Video" and view video.

Resources:

1. "Stream Ecology Basics Sampling Training Guide" http://www.dlia.org/dlia/education/activities_stream_ecology.pdf
2. "Healthy Water Healthy People" Testing Kit Manual

Stream Ecology Basics

Monitoring streams and rivers yields a greater understanding of processes and patterns in the watersheds where people live, play and work. Monitoring programs can help to build local awareness of water quality issues and may play an important role in decision making by private agencies and local, state and federal governments. Stream monitoring is an effort to better understand how streams are affected by human and natural processes. All streams are unique, yet they all share similar features and properties. It is the similarity between streams that enables us to make comparisons between them and draw general conclusions about stream health and water quality.

In general, benthic macroinvertebrates (benthic: “bottom dwelling, living below the water surface on the substrate”; macro: “visible to the naked eye”; invertebrate: “animal lacking a backbone”) are a collection of insects and crustaceans such as stoneflies, midges, snails, and crayfish. These organisms are commonly monitored to help us evaluate the water quality of our surface waters, they serve as tiny, living water quality indicators. Macroinvertebrates serve as good indicators of overall stream health for several reasons: they are relatively common and easy to collect, they occupy several trophic levels within a lake or stream, some of them have long life cycles of a year or more and are exposed to environmental changes throughout their lifespan, and they cannot move to avoid poor water quality conditions. Different macroinvertebrates have different reactions to pollution. Some are very tolerant and can live in any water conditions, but others are very sensitive and can only survive in good water quality conditions. As a result, the presence or absence of macroinvertebrates can effectively illustrate the conditions of our local streams, rivers, and lakes.

Water Quality Parameters

Alkalinity = total measure of the substances in water that have “acid-neutralizing” ability, the power to keep its pH from changing.

Importance and Explanation? Important for fish and aquatic life because it protects or buffers against pH changes, keeping the pH fairly constant, and makes water less vulnerable to acid rain. The main source of natural alkalinity is rocks (limestone), which contain carbonate, bicarbonate, and hydroxide compounds that dissolves into basic solution.

Measured in? mg/l or mg/l $CaCO_3$

Conductivity = measure of how well a water sample conducts electricity and an estimate of the total dissolved solids in a sample.

Importance? Presence of ions in water makes it a good conductor of electricity. Ions that are often found in natural waters include: calcium, aluminum, magnesium, sodium, potassium, carbonate, bicarbonate, phosphate, chloride, nitrate, and sulfate. Temperature of the water affects the conductivity measurement. The conductivity is affected by the nature of the ions, and by viscosity of the water. In low ionic concentrations (very pure water), the ionization of the water furnishes an appreciable part of the conducting ions.

Measured in? microsiemens/cm by a voltmeter and conductivity probe

Dissolved Oxygen (DO) = amount of oxygen that is dissolved in water.

Importance and Explanation? Measuring DO in water indicates how much DO is present but not how much oxygen the water is capable of dissolving. The dissolved oxygen gets into the water by diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids; and as a waste product of photosynthesis. The colder the water temperature, the more oxygen can be dissolved in it. How much DO an aquatic organism needs depends upon its species, its physical state, water temperature, pollutants present, and more.

Measured in? mg/l or ppm; to convert percent dissolved oxygen to mg/l, multiply by 1.33

Water Quality Parameters Continued

Nitrate = measures the organic or fertilizer matter in water.

Importance and Explanation? Nitrite and Nitrate are forms of the element Nitrogen, which makes up about 80 percent of the air we breathe. As an essential component of life, nitrogen is recycled continually by plants and animals, and is found in the cells of all living things. Nitrogen is unavailable for plant use in its most common form, atmospheric nitrogen (N_2); therefore, nitrate often becomes a limiting nutrient for plant growth. Nitrates stimulate the growth of plankton and water weeds that provide food for fish. This may increase the fish population. However, if algae grow too wildly, oxygen levels will be reduced and fish will die.

Measured in? mg/l

pH = measures the hydrogen ion concentration or activity on a logarithmic scale.

Importance and Explanation? The hydrogen ion concentration determines the pH of a solution. pH is referred to as hydrogen ion concentration or activity. An acid is a solution with more hydrogen ions than hydroxide ions. The pH test measures the hydrogen ion concentration and allows us to infer how acidic or basic a substance is. The pH scale is logarithmic and for every one unit of change in pH there is a ten-fold change in the hydrogen or hydroxide ion concentration of the solution.

Measured in? No units

Phosphate = measures the organic or fertilizer matter in water.

Importance and Explanation? Phosphorus is an essential nutrient for all forms of terrestrial life and is known to be required for plant growth, storage, and transmission. Phosphates are found in the mineral apatite, which occurs naturally in igneous, metamorphic, and sedimentary rocks. However, more than half of the phosphates found in lakes, streams, and rivers are the result of human activity. Discharge of animal and human wastes, industrial and domestic wastes, and fertilizers introduce phosphates into natural waters.

Measured in? mg/l

Temperature = measures the average amount of heat in the water.

Importance and Explanation? Temperature dictates metabolic function, reproductive timing and duration of the life cycle of aquatic organisms. Air temperature may change by 20°C in a 24 hour period; however, water temperature will change insignificantly in a 24 hour period. The concept of specific heat is critical to understanding water temperature measurement. Water has a high specific heat because it takes a large amount of heat to break hydrogen bonds, the attraction of one water molecule to another water molecule. Fish and most aquatic organisms are cold-blooded. Consequently, their metabolism increases as the water warms and decreases as it cools. Each species of aquatic organism has its own optimum (best) water temperature.

Measured in? degrees Fahrenheit (F) or degrees Celsius (C)

Turbidity= cloudy appearance of water caused by light scattering suspended particles.
Transparency (Clarity) = measures the clearness of water and is an indicator of how well light passes through it.

Importance and Explanation? Any substance that makes water cloudy will cause turbidity. The most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from logging, mining, and dredging operations. Turbidity affects fish and aquatic life by interfering with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis—and the production of oxygen for fish and aquatic life—will be reduced.

Measured in? Turbidity: Nephelometric Turbidity Units or NTUs by an electronic turbidimeter and Clarity: Meters or centimeters by a secchi disk or transparency tube

On-Site Activity
Water Quality Study

Grade Level: High School

Subject Area: Science

Activity time: 75 minutes

Setting: Outdoors in the park

Skills: Categorizing, Classifying, Collecting information, Communicating, Connecting, Experimenting, Gathering information, Identifying cause and effect, Interpreting, Proposing solutions, Recording data, Role playing, Sorting

Objectives:
1) demonstrate the ability to collect and record data
2) search for and identify benthic macroinvertebrates in the stream
3) describe the threats on streams and macroinvertebrate life in the streams
4) explain why it is important to study water quality and its benthic macroinvertebrates

Materials: provided by the rangers
- Transparency tube
- Nitrite/nitrate test strip
- pH test strip
- Phosphate strip test
- Alkalinity test strip
- Thermometer for soil, water, and air
- If available: conductivity probe and dissolved oxygen probe
- Net
- Macroinvertebrate key
- Plastic containers to view macroinvertebrates

Background:
The ranger will explain to the students that the Smokies has over 2,100 miles of rushing mountain streams and rivers that flow through the park. In each mile lives a diverse community of native fish, amphibians, insects, and larvae, some of which are found only in the Southern Appalachians. Besides things we hope to find in our water, however, there are also many things that threaten Smokies' streams: chemical contaminants, metals leached from rocks and soil, diseases, and non-native plants and animals. To tackle these issues, park fisheries managers and university researchers monitor water quality, fish populations, and watersheds to better understand the dynamics of water running through diverse ecosystems. The park uses this science information to make rules about fishing, restore populations of native and endangered fish, and even influence national pollution laws. The park also uses this information to educate the public and visitors about how they can help keep Smokies streams healthy. This particular stream at Purchase Knob has been tested and monitored for several years. During the study the students will assist the ranger(s) in collecting the data from the stream.

Post-Site Activity
Graphing Elevation Trends

Grade Level: High School

Subject Area: Science

Activity time: 60 minutes

Setting: Classroom

Skills: Analyzing, Applying, Assessing, Calculating, Charting, Communicating, Connecting, Contrasting, Discussing, Evaluating, Generalizing, Graphing, Inferring, Predicting, Summarizing

Objectives:

1) demonstrate the ability to graph provided data
2) describe the trends seen from the graph
3) communicate the park-wide trends of water quality within the park

Materials:

•"Great Smoky Mountains Watershed Elevation Trends" worksheet (pages 13-14)
•"General Program Observations" (pages 15-16, to be given out AFTER the elevation graphing activity)

Background:

Great Smoky Mountain watersheds show distinct differences in geology and morphology with elevation (example: steeper slopes at higher elevations). Differing elevations show differing levels of the various parameters. Ask students to hypothesize some reasons why elevation would affect the pH, ANC, nitrates, and sulfates.

Procedure:

Have the students individually study the table of provided information of elevation versus several parameters. The students should construct a graph of elevation versus pH, elevation versus ANC (Acid Neutralizing Capacity), elevation versus nitrate, and elevation versus sulfate. Remind the students to label their axes. After graphing, the students should be able to use the graph to summarize in words what trends they see within the graph. Additional information, "General Program Observations," is to be given to students AFTER the graphing and summary of graphing has taken place.

Regroup the students upon completion of the graphs and summary. Compare answers as a group. Give out additional information "General Program Observations." After giving appropriate time for reading, compare thoughts and feelings as a group.

Great Smoky Mountains Watershed Elevation Trends

Great Smoky Mountain watersheds show distinct differences in geology and morphology with elevation (example: steeper slopes at higher elevations). Different fish species are more common in different elevation ranges.

Comparison of Different Parameters in regards to Elevation

Current Conditions

Elevation (ft)	pH	ANC (μeq/l/yr)	Nitrate (kg/ha)	Sulfate (μeq/l/yr)
1,000-1500	6.66	145.8	10.5	44.2
1,500-2,000	6.57	200.9	11.5	35.6
2,000-2,500	6.34	59.6	12.8	32.8
2,500-3,000	6.30	51.6	18.8	36.8
3,000-3,500	6.12	30.9	23.9	42.9
3,500-4,000	6.18	41.5	35.2	71.2
4,000-4,500	5.85	22.3	34.7	74.8
4,500-5,000	5.74	31.6	34.6	72.8
5,000-5,500	5.66	18.1	49.9	37.7
>5,500	5.11	2.1	64.3	38.0

Construct a graph of elevation versus pH, elevation versus ANC (Acid Neutralizing Capacity), elevation versus nitrate, and elevation versus sulfate. Remember to label your axes.

A. Elevation versus current pH

B. Elevation versus ANC

C. Elevation versus nitrate

D. Elevation vs sulfate

Great Smoky Mountains Watershed Elevation Trends Continued

Summary of Graphs

A. By viewing your graph, what is the overall trend of elevation versus pH?

B. By viewing your graph, what is the overall trend of elevation versus Acid Neutralizing Capacity (ANC)?

C. By viewing your graph, what is the overall trend of elevation versus nitrate?

D. By viewing your graph, what is the overall trend of elevation versus sulfate?

General Program Observations of Water Quality Testing in The Park

• A parkwide water quality program began in 1993 as a cooperative effort between the National Park Service, University of Tennessee, and Trout Unlimited (TU)
• The basic design was to co-locate water quality, fish and aquatic insect sites in select watersheds
• 32 sites sampled bi-monthly in 7 watersheds (Cosby Creek, Little River, Abrams Creek, Oconaluftee River, Little Pigeon, Cataloochee Creek)
• TU volunteers hiked >5,000 miles over last 15 years
• Scientists and volunteers collected at least 11,048 water samples from 1993 -2007

Park-wide Trends

pH
• 77% of the sites sampled have a median pH<6.5 (Robinson et al. 2005)
• pH is declining at 0.2 units/yr at elevations 1,000-3,500 feet but there is no change above 3,500 feet
• If current trends continue, median pH of Little River at Elkmont (elev. 2,146') will be 6.0 in 34 years, and at many other sites <25 years (Robinson et al. 2007)
• During storm events, pH may drop as much as 2 full units, Al- (High levels of aluminum are toxic to fish, so biologists expect to see increased die-offs as this common metal rushes into streams from soil after storms).

Acid Neutralizing Capacity (ANC)
• 95% of GRSM streams have acid neutralizing capacities (ANC) <25 µS/cm (sensitive or extremely sensitive to acidification) (Robinson et al. 2005); sandstone geology coupled with thin soil profiles provide little buffering capacity
• ANC, pH, Na+, K+ decrease as elevations increase (Robinson et al. 2005)
• No general trend over time was observed for ANC (Robinson et al. 2007)
• Scientists are beginning to think that the slight acidity of normal rainwater helps the soil capture the small amounts of acid that normally fall, creating a chemical "sponge" so the soil can hold and buffer low amounts of sulfates

Nitrate & Sulfate
• Nitrate (NO_3) and sulfate (SO_4) are the major pollution sources (Robinson et al. 2005). Levels of these increase as elevation increases; primary source of nitrate = auto exhaust; sulfate = coal-fire plants
• Sulfate is declining at a rate of -0.83 to -1.3 eq/l/yr at elevations less than 3,500 feet, which is consistent with decreasing atmospheric sulfate deposition; this is similar to rates seen at Hubbard Brook (Gbondo-Tugbawa and Driscoll 2002) from low to high elevation (Robinson et al. 2007)
• Nitrate concentrations and total N deposition (kg/ha) show no change, although ammonia and nitrate in precipitation has been declining (Robinson et al. 2007). There was elevated nitrogen and cations leaching in soils following hemlock decline and mortality (Yorks et al. 1999)
• Adding more sulfate and nitrate to the nutrient system disrupts the balance. Plants can store a certain amount of nitrates, and soils can store a certain amount of sulfates, but we have already exceeded this necessary amount. Excess acid then washes straight into the stream, taking with it metals and nutrients such as calcium from the soil. This disrupts natural levels of magnesium, potassium, and sodium
• Soil pH lowest and exchangeable Al and Fe are highest under hemlock (Fenzi 1998)
• Replacement of hemlocks by hardwoods is likely to result in increases in pH and N turnover rates, reductions in forest floor carbon and nitrogen, and reductions in exchangeable cations (Yorks et al. 2004)

General Program Observations Continued

Impacts to Aquatic and Non-Aquatic Organisms

- Softer waters significantly increase mortality of embryos (Johnson 2002)
- Organisms will have reduced growth due to nitrate exposure (Johnson 2002)
- Larvae and later life stages are more resistant to NO_3 than early life stages (i.e. eggs); groundwater nitrate levels are a concern (Johnson 2002)
- The density of brook trout is negatively correlated to time since logging (Nislow and Lowe 2003)
- Acid rain kills different fauna in many different ways:
    1. By stressing these ecosystems to the point where they are vulnerable to insects and diseases
    2. By leaching ions out of the soil that are toxic to various species
    3. By inhibiting metabolic, cellular processes, or reproductive functions

Acid-sensitive animals include brook trout, salamanders, mayflies,caddisflies, and more. They start to disappear when a stream's average pH dips below 5.0. When the pH drops below 4.0, almost all animals disappear

Changes in soil chemistry have serious consequences for plants and animals:

- Land snails that can't absorb enough calcium from soil can't build strong, spiral shells
- Birds that rely on a diet of snails to boost their own calcium levels do not receive enough of the nutrient, and in turn their eggshells are weakened

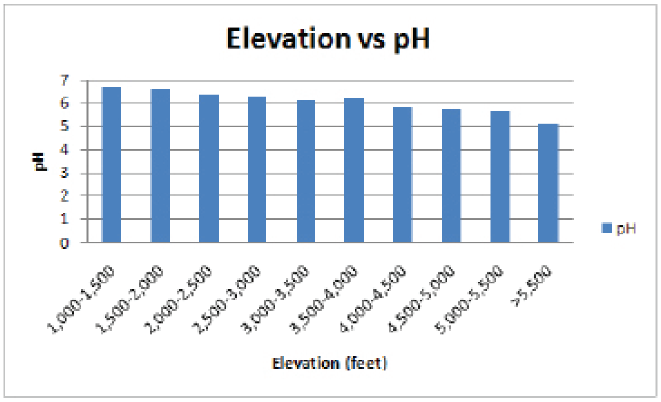
A pH regression model shows a strong elevation trend of -0.72 pH unit/1,000 m increase in elevation. Given that there is a 1,300m (4,270 ft) difference in elevation within the Great Smoky Mountains National Park, this means that pH should be about one unit lower at higher elevations (1,725m or 5,660 ft) compared to lower (425 m or 1,390 ft)

What the future looks like . . . if the current trends continue:

	Current	Years to pH of		
Elevation (ft)	pH	6.5	6.0	5.5
1,000-1,500	6.66	26	46	67
1,500-2,000	6.57	13	26	39
2,000-2,500	6.34	14	32	50
2,500-3,000	6.30	11	26	42
3,000-3,500	6.12	4	15	26

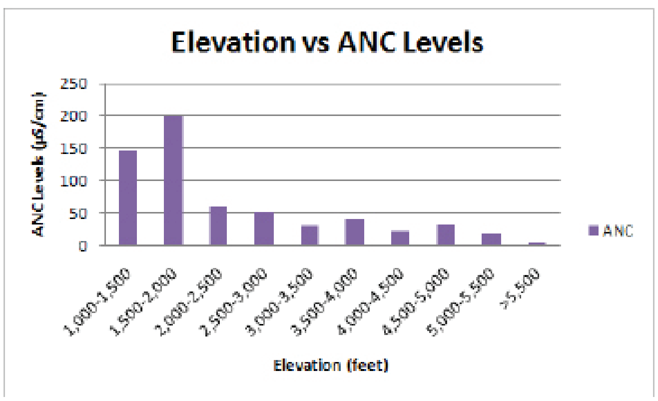
GRSMNP Watershed Elevation Trends
Teacher Answer Key

Summary of Graphs



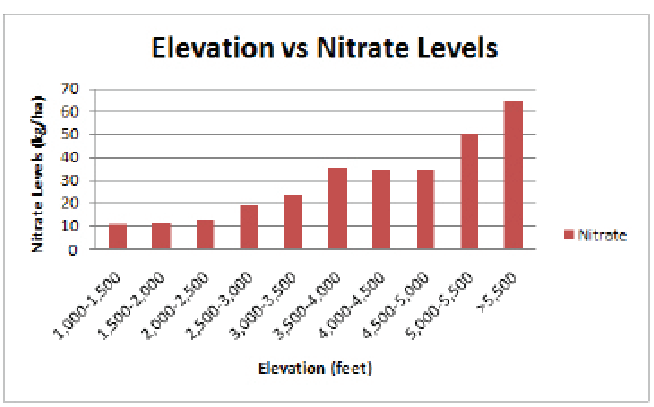
A. By viewing your graph, what is the overall trend of elevation versus pH?
pH decreases as elevation increases.

Teacher Information: pH is declining at 0.2 units/yr at elevations 1,000-3,500 feet but no change above 3,500 feet. If current trends continue, median pH of Little River at Elkmont (elev. 2,146 feet) will be 6.0 in 34 years, many others <25 years (Robinson et al. 2007)



B. By viewing your graph, what is the overall trend of elevation versus ANC?
ANC levels generally decrease as elevation increases.

Teacher Information: 95% of GRSM streams have acid neutralizing capacities (ANC) <25 µS/cm (sensitive or extremely sensitive to acidification) (Robinson et al. 2005); sandstone geology coupled with thin soil profiles provide little buffering capacity. ANC, pH, Na+, K+ decrease as elevations increase (Robinson et al. 2005)

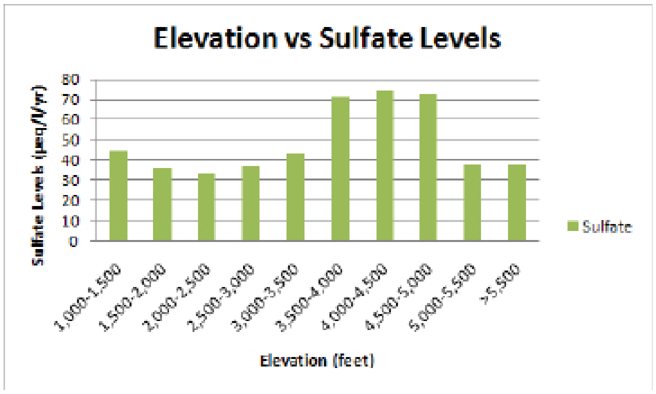


C. By viewing your graph, what is the overall trend of elevation versus nitrate?
Nitrate concentrations increase as elevation increases.

Teacher Information: Nitrate concentrations and total N deposition (kg/ha) show no change, although ammonia and nitrate in precipitation has been declining (Robinson et al. 2007). There was elevated nitrogen and cations leaching in soils following hemlock decline and mortality (Yorks et al. 1999)

GRSMNP Watershed Elevation Trends Teacher Answer Key Continued

EFFECTS OF AIR & WATER POLLUTION
WATER QUALITY MONITORING



D. By viewing your graph, what is the overall trend of elevation versus sulfate?
Sulfate concentrations decrease from 1,000-2,000 feet and increase from 2,000 feet until 5,000 feet and then decrease.

Teacher Information: Sulfate concentrations have been declining at a rate of -0.83 to -1.3 eq/l/yr at elevations less than 3,500ft consistent with decreasing atmospheric sulfate deposition; similar to rates seen at Hubbard Brook (Gbondo-Tugbawa and Driscoll 2002) from low to high elevation (-1.2 to -2.5 eq/l/yr) (Robinson et al. 2007)

Extra Teacher Information:
Some students may ask why the future pH's are not changing in the higher elevations (seen on "General Program Observations" worksheet). The scientists at this point are not sure but have a general idea what is happening. First, these high elevation areas have been hammered by acidification for many years and are basically nitrogen saturated and base cation depleted. Recent soils work suggests even if we completely stopped the influx of nitrogen and sulfate today, stream acidification would continue for many years simply due to the amount of material bound in the soil layers. The process of soil buffering slowly moves down slope as buffering capacity diminishes and soil become saturated. Mid-to-low elevation areas are now the transition area where what little soil buffering capacity still battles with episodic inputs from storms in a never ending battle. It will eventually either become saturated and lose most all its buffering capacity (like high elevation areas) or begin to "fix" itself by retaining more base cations in the soil than are leaving each year, thus increasing buffering capacity. This process would them move back up slope as soils improve. Additionally, the samples sizes were fairly low so more data points would probably show a significant negative trend.