Alice Ferguson Foundation's

BRIDGING THE WATERSHED

DON'T GET SEDIMENTAL

Runoff and Sediment in the River

An outreach program of the Alice Ferguson Foundation in partnership with the National Park Service and area schools that offers secondary school students opportunities to study real-world science in national parks.

Teacher's Guide & Resources

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MODULE ORGANIZER

This module is divided into three sections: activities completed prior to the park visit (Pre-Field Studies), the field study conducted in the park (Field Study), and the activities completed subsequent to the park visit (Post-Field Studies). In the Pre-Field study activities students will examine the impact of land use on streams in their watershed and will explore the sources of sediments, the excess nutrients carried with them, and the effects of these excess nutrients on water quality. They will also study how changes in population affect land use. In the field study, your students will collect authentic data in a national park in the Potomac River watershed to assess how runoff affects stream habitat. After their park visits, students will conduct data analysis to share their findings. Students will then explore ways to minimize runoff and sediment through low-impact development. Finally, students complete an action project that addresses an environmental issue in their community and school. Completing all parts of this module will achieve a Meaningful Watershed Educational Experience (MWEE), a learner-centered framework that focuses on investigations into local environmental issues and leads to informed action. This module ensures that the MWEE is done thoughtfully to increase student environmental literacy.

Note: The teacher guide includes all the lessons, including student sheets. The student materials are included with the supplementary materials and can be printed out as needed.

TITLE	GOAL(S)	MATERIALS LIST
	PRE-FIELD STUDY	
Bay in a Beaker	To explore the effects of excess nutrients on an aquatic ecosystem.	• 5 1-liter beakers or other transparent, colorless containers • Marker to write on plastic or glass • 3 liters of water from a pond, stream or bay • 1 liter of distilled water • Balance • Paper Bag • 70 mg plant fertilizer (10-10-10 suggested)
Potomac River Basin Timeline	To construct a timeline showing how land use by a growing population has impacted the waterways in the Potomac River watershed over the last 400 years.	• Colored markers • 1-meter paper strip • Meter stick
Color Me a Watershed	• To explore the effects of population growth and land use on runoff in a typical watershed. • To evaluate how changes in land use affect runoff.	• Colored pens/pencils: blue, green, orange, red, yellow, brown • For extensions, computer with Excel program and Internet access
	FIELD STUDY	
Assessing Stream Health	To assess the impact of sedimentation on the health of a stream habitat in a local national park.	• Appropriate clothing • Adequate food and water • All other materials will be provided
	POST-FIELD STUDY	
Data Analysis	To compile class data in order to rate the effects of sedimentation and runoff on the health of the stream habitat.	• Data collected on field study • Data from other field studies, found on BTW teacher resource webpage • Computer with Internet access

TITLE	GOAL(S)	MATERIALS LIST
POST-FIELD STUDY		
Great Terrain Robbery	To explain the effect of land use on runoff, erosion, and water quality.	For each group of 3-4 students: • 6 dishpans notched in one end, with spouts attached (see the illustration of the experiment setup) • Soil for all the bins (the same amount and type) • Soil cover materials: compacted soil, mulch, grass sod, asphalt shingles or plastic sheeting (something impermeable) • One watering can per dishpan of soil (same size and type) • 1-liter measuring containers • A large-mouthed collection vessel for the runoff from each dishpan – these should be identical in size and shape and clear-colored • A prop for each dishpan (2x4's work well). All the bins need to be at the same slope • Turbidity test kit
Student Action Project: Take Action!	To increase awareness of the need for individual environmental action.	• Computer with Internet access
RESOURCES		
These resources will provide additional information on the subjects of all the activities. Teachers may use them as a personal reference, or may assign them to students as further reading.		

Note: The overview module, "Potomac River Watershed: Water, Water, Everywhere," contains several activities that introduce the concept of a watershed and nonpoint source pollution that are excellent supplements to this module. "Who Polluted the Potomac," also in the overview module, provides a basic understanding of nonpoint source pollution.

Next Generation Science Standards

Performance Expectations	
MS-LS2-4	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-LS2-5	Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
MS-ETS1-3	Analyze and interpret data to determine similarities and differences in findings among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ESS2-5	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Constructing Explanations and Designing Solutions • Analyzing and Interpreting Data • Engaging in Argument from Evidence • Constructing Explanations and Designing Solutions • Planning and Carrying out Investigation	• LS2.C Ecosystem Dyanmic, Functioning, and Resilience • LS4.D: Biodiversity and Humans • ETS1.B Developing Possible Solutions • ETS1.C Optimizing the Design Solution • ESS2.C The Roles of Water in Earth's Surface Processes	• Stability and Change • Cause and Effect • Structure and Function

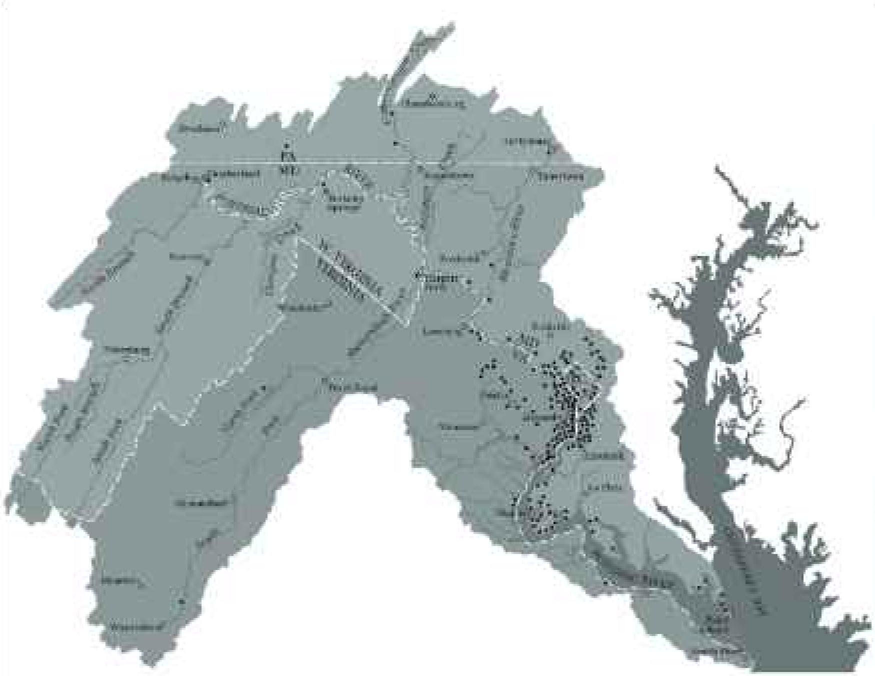
Introduction to Don't Get Sedimental

BACKGROUND INFORMATION:

Particles of sediment comprise both organic and inorganic matter, offering a vast surface area capable of attracting and retaining various molecules, including nutrients, oils, pesticides, metal ions, and potentially harmful substances. Accumulation of sediment in certain areas can lead to heightened concentrations of persistent pollutants such as pesticide residues and heavy metals. Suspended sediment contributes to water turbidity, reducing light penetration essential for plant growth. Upon settling, sediments may fill water bodies, suffocating bottom-dwelling flora and fauna. Furthermore, sediments can exacerbate eutrophication by carrying nutrients.

This module is designed to heighten students' awareness about the watershed in which they live and help them understand the important role they play in the health of the watershed. Students will explore the impact that runoff and sedimentation from increasing development have on the watershed.

Explain that the student handouts contain the procedure for completing activities as well as a place to record data and respond to questions. Resources, at the end of this module, contain reference material needed to complete the activities



Goal:

To introduce students to the scientific concepts and activities in this module.

Class Time:

20 minutes

Special Considerations:

A map showing the Potomac River watershed, the Chesapeake Bay watershed, and your school location will help orient students.

Review Bridging the Watershed at fergusonfoundation.org

Bay in a Beaker

ENGAGEMENT

BACKGROUND INFORMATION:

Cultural eutrophication is the accelerated growth of algae and plant life resulting from the artificial enrichment of waterways with nutrients that cause an overgrowth. Though runoff from farms and feedlots is the source of many of these nutrients, the application of commercial fertilizers to suburban lawns and their subsequent runoff is a much more significant source. Algae, like all plants, benefit from the nutrients in fertilizer (whether manure or commercial mixture), but while multicellular plants may simply grow bigger or greener, algae and other microscopic photosynthetic organisms undergo population explosions. This causes the water to become cloudy and green, preventing sunlight from reaching plants rooted in the bottom. Those plants die and do not produce more oxygen. Algae live only a short time, and when the large populations die, decomposition by oxygen-using bacteria further depletes the supply of dissolved oxygen. As a result many aquatic organisms must either leave the area or die.

In "Bay in a Beaker," students study the factors affecting eutrophication in pond water when commercial plant fertilizer is added. This activity is both interesting to students and critical to their understanding of the problems that human activities pose for our waterways.

This lab is an introduction to basic experimental design and the scientific process. Collect stream (or pond, river, bay) water in a well-rinsed glass container (soap residue can be toxic to microorganisms). Do not use metal and avoid plastic containers unless they are new. Do not use fertilizer that contains herbicides because they will kill the algae. Place prepared beakers in a sunny spot, but not on top of a heater unless it is off (too much heat will affect the results).

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **What is a nutrient?**

   A nutrient is any substance considered "food" for an organism. Nitrogen and phosphorous are two primary nutrients essential for plants (aquatic and terrestrial) and animals, including humans.

2. **Why do people use fertilizer on lawns and agricultural crops?**

   People use fertilizers to help plants grow better or to grow more plants. Fertilizers contain nutrients for plants that may not be present in the soil.

3. **We are going to conduct an experiment to measure the effects of nutrients on stream water.**

Goal:

To explore the effects of excess nutrients on an aquatic ecosystem.

Class Time:

- Day 1: 45 minutes to 1 hour
- Day 5: 15 minutes for observation and data recording
- Day 10: 30-45 minutes for summarizing data, answering questions and discussion of results and implications.

Group Size:

Groups of 2-3 students

Materials for Each Group:

- 5 1-liter beakers or other transparent, colorless, containers
- Marker to write on plastic or glass
- 3 liters of water from a pond, stream, or bay
- 1 liter of distilled water
- Balance
- Paper bag (large enough to fit over one container)
- 70 mg plant fertilizer (Note: Do not use fertilizer that controls weeds. The herbicide will also kill algae. 10-10-10 is suggested.)

Special Considerations:

Use a digital camera to show changes.

Bay in a Beaker

ENGAGEMENT

Give a short overview of the setup and lead a discussion of the experimental process: what hypothesis do students want to test; which beaker is your control?; what is the variable?

> **New Terms and Topics:**
> Cultural Eutrophication
> (See the Resources section for definitions and more information on these terms.)

4. **We are going to conduct an experiment. Label the beakers 1, 2, 3, 4, 5 and date each one.**
5. **Fill beakers 1, 2, 3, and 4 with 750 mL of water from a stream, pond, river, or bay.**
6. **Fill beaker 5 with 750 mL of distilled water.**
7. **Weigh 10 mg of fertilizer. Add this to beaker 1.**
8. **Weigh 25 mg of fertilizer. Add this to beaker 2.**
9. **Weigh 10 mg of fertilizer. Add this to beaker 3.**
10. **Cover beaker 3 completely with a paper bag so that no light can enter the beaker.**
11. **Do not add any fertilizer to the water in beaker 4.**
12. **Weigh 25 mg of fertilizer and add this to the distilled water in beaker 5.**
13. **Place all the beakers in a sunny windowsill or under a bright light. Do not seal the beakers. You will examine and record observations on days 1, 5, and 10.**
14. **What is the purpose of the bag covering beaker 3?**

    Beaker 3 will show what effect the absence of light might have on the outcome. It will show whether the fertilizer alone produces cloudiness in the water.

15. **What is the purpose of beaker 4?**

Beaker 1	Beaker 2	Beaker 3	Beaker 4	Beaker 5
750 mL stream H_2O	750 mL stream H_2O	750 mL stream H_2O	750 mL stream H_2O	750 mL Distilled H_2O
10 mg fertilizer	25 mg fertilizer	10 mg fertilizer	**(Control – No fertilizer)**	10mg fertilizer
		(Cover with paper bag)		

This is your control. Since this beaker has stream water but no fertilizer, it will show what happens in a "natural " aquatic situation in which there is light but not excessive nutrients from farm or lawn runoff.

16. What is the purpose of beaker 5?

This beaker contains fertilizer, but because the water is distilled, this beaker will show what the water will look like when no organisms are present to use the nutrients.

17. Write a prediction to describe what you think will happen in each beaker.

Depending on prior knowledge, students may or may not have a basis for their predictions. It's okay for students to formulate incorrect predictions because finding they are incorrect may be as valuable as predicting correctly. Students will write their predictions in Table I in their booklet (Table I below describes the possible actual changes occurring in each beaker).

TABLE I

Beaker	Actual Changes
1	**Stream water + fertilizer + sunlight.** Stream (or pond or river or bay) water will contain organisms including various forms of algae. Since algae use nitrogen and phosphorus to grow and multiply, the algae population should increase and the water should get cloudier and greener. As the fertilizer is used up, there should be an accumulation of dead algae on the bottom.
2	**Stream water + 2.5 times as much fertilizer as Beaker 1 + sunlight.** The same thing that happens in Beaker 1 should happen in Beaker 2 for the same reasons, except that there should be heavier algae growth and a greater accumulation of debris from the higher populations of dead algae.
3	**Stream water + fertilizer + no sunlight.** This beaker has the same combination of factors as Beaker 1 except that the bag over the beaker should prevent algae growth because photosynthesis stops in the absence of sunlight. They should not be able to multiply, so they should die, and the water may actually get clearer as time goes by. Depending on how much algae was present at the beginning, the water may also become gray and cloudy as decomposition bacteria break down the dead algae. There may also be an odor of decay and a build-up of debris on the bottom.
4	**Stream water + no fertilizer + sunlight.** Though there should be a starting algae population equivalent to beakers 1– 3, there is no fertilizer added to provide the excess nutrients. There may be a little increase in green cloudiness in this beaker, however, since the sunlight, warmth, and absence of many predators may allow the population to increase to its natural maximum.
5	**Distilled water + 10mg fertilizer.** There will be little or no algae growth. Color will remain what it was after fertilizer was added. Turbidity will not increase.

18. Record your observations in Table II.

Student observations will vary here, but ideally there should be a progression in the direction of the predicted results explained in the "Background Information" at the start of this activity. You may use a standard measure of turbidity for clarity.

Bay in a Beaker

ENGAGEMENT

TABLE II: OBSERVATIONS

Beaker	Day 1	Day 5	Day 10
1	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
2	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
3	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
4	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
5	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:

19. After 10 days, use your observations in Table II to help you:

1) Summarize the changes you observed in each beaker and 2) determine whether your observations support the predictions you made in Table I. Record your responses in Table III.

Note: The Prediction Supported column's answers depend on students' predictions.

TABLE III (EXAMPLE)

Beaker	Summary of Changes	Prediction Supported?
1	Second cloudiest, second greenest, with second most debris present.	Yes
2	Cloudiest, greenest, lots of debris on the bottom. Got smelly at the end.	Yes
3	Got clearer, a lot of debris present on the bottom.	No
4	Stayed basically the same, some debris present.	Yes
5	Unchanged.	Yes

Bay in a Beaker

ENGAGEMENT

20. Explain the process of eutrophication. (Refer to the article on "Effects of Pollutants on the River" on page 37 of the Resources Section.)

All kinds of plants, including algae, use the same nutrients. When fertilizer from the land gets into waterways, the fertilizer encourages plant growth. Algae are one-celled and can reproduce quickly, so an algae population explosion occurs. This clouds the water and prevents light from reaching the plants rooted at the bottom, so they die. Dissolved oxygen remains high near the surface where the algae are, but is reduced near the bottom. This stresses or kills the bottom-dwelling organisms that need oxygen. As the increased numbers of algae die, the bacteria decomposing them increase in numbers. Since the decomposition process uses oxygen, the amount of dissolved oxygen is further reduced, and the aquatic ecosystem becomes more depleted.

21. Which beaker(s) represent cultural eutrophication that is the result of runoff from farms and fertilized lawns? Explain.

Beakers 1 & 2. These beakers contained stream water with microorganisms such as algae. When fertilizer was added, it provided an excess of nutrients that the algae used to grow and reproduce. Therefore, the algae population increased greatly. This made the water cloudier and greener. This is the same thing that happens when fertilizer in the runoff from farms and fertilized lawns gets into natural bodies of water. Algae growth increases, clouds the water, and blocks the light from plants below. Since the algae die after a few days and are broken down by bacteria, the population of bacteria in the water also increases, adding a gray cloudiness and a bad smell. Cultural eutrophication is a rapid acceleration of the natural process of eutrophication, which happens at about the rate of geological processes.

22. Did your observations support your prediction? Explain.

Potomac River Watershed Timeline

EXPLORATION

BACKGROUND INFORMATION:

Four hundred years ago, significantly fewer humans lived in and around the Washington, D.C. area. When the number of people inhabiting an area increases, it changes the land and the waters of the region. A timeline is one way to illustrate the changes that have occurred over time.

Land use in the Washington area over the last 400 years has been increasingly urbanized. Agricultural land and forests have been replaced by homes, schools, businesses, and roads. Much of the open land has been covered with impervious surfaces (roads, sidewalks, buildings, parking lots). Humans have deliberately altered bodies of water to enhance the living environment or to facilitate commerce. Erosion and sediment deposition have also altered bodies of water.

Human activities have greatly accelerated natural processes and created a myriad of pollution problems. Once the problems exist, they must be recognized, and steps must be taken to correct them. However, it is important for students to understand that environmental problems cannot be corrected quickly and to recognize when improvements have occured. In this activity, students will explore the changes in the Potomac River watershed over the last 400 years and the impact of humans on the river and its tributaries.

PREPARATION:

Cut a paper strip 1 meter long for each group of 2 students.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **How old is your school?**

2. **How old is the building in which you live?**

3. **How old is the local shopping mall?**

   Answers will vary, but in most cases, students' homes, schools, and many buildings in their communities did not exist 50 years ago.

4. **Imagine your community 50 years ago. Make a list of things you could find today that were there 50 years ago.**

   The bodies of water themselves, certain older buildings, some bridges, some trees, and natural formations like caves are the kinds of things students should recognize as having been present 50 or more years ago.

Goal:

To construct a timeline showing how land use change and a growing population have affected the waterways in the Potomac River watershed over the last 400 years.

Class Time:

45 minutes

Group Size:

Groups of 2 students

Materials List for Each Group:

- Colored markers
- 1-meter paper strip (receipt tape works well)
- Meter stick

Special Considerations:

This is an open-ended activity requiring critical thinking. The students' timelines will vary. Students should be able to justify their choices and explain why each date fits each category. Students need to be able to find the Chesapeake Bay, the Potomac River, and the Anacostia River on a map.

New Terms and Topics Introduced in thisActivity:

Sedimentation

Potomac River Watershed Timeline

EXPLORATION

5. Draw a vertical line across one end of the paper strip. Label this line "1600."

6. One centimeter represents 5 years, and 2 centimeters represent a decade or 10 years.

7. Using this scale, start at the 1600 line and draw a line for each decade from 1600 to the present.

8. Read carefully the "Potomac River Watershed Timeline" distributed by your teacher.

9. Using a different color for each issue, draw a horizontal line on your 1-meter paper strip, beginning when each of these problems was first noted and continuing up to a date when the problem was solved:
   - Brown: sedimentation (soil erosion)
   - Blue: sewage (bacterial contamination)
   - Green: cultural eutrophication (excess nutrients such as nitrogen or phosphorus)
   - Red: chemical pollution (such as acids from mining, or urban and industrial runoff)
   - Purple: trash and litter pollution

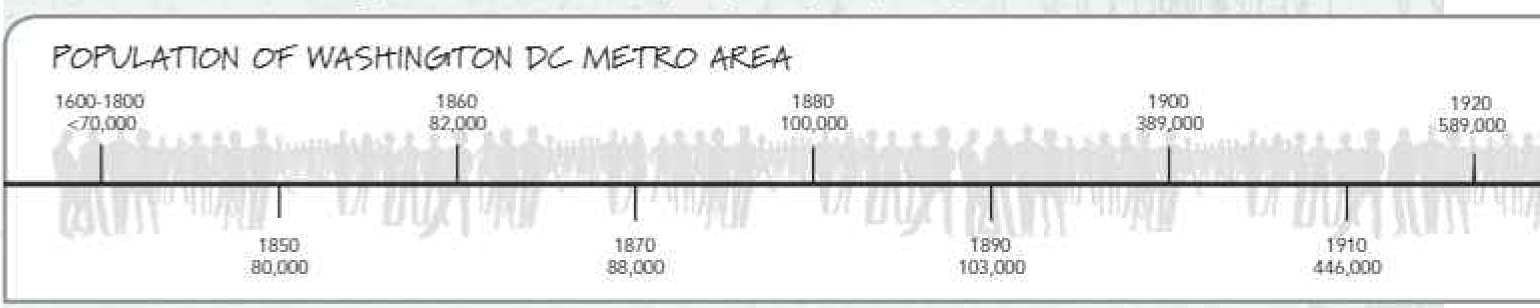
   Line for sedimentation should begin at 1750; sewage at 1810; eutrophication at 1932; chemical pollution at 1894; trash at 1950; thermal pollution at 1951. All lines should continue to present.

10. On each colored line, draw an "X" at the year in which an attempt to address this problem was made. Using the same color, circle the date in the "History" that represents this "X."

    Possible Responses:
    - Sediment problems begin in 1750. "X" at 1870 and 1970 as years of specific action to control sediment.
    - Sewage problems begin in 1810. "X" at 1938 (construction of Blue Plains), 1948, 1959 as years of action to address sewage problems.
    - Cultural eutrophication begins in 1932 (described as lower dissolved oxygen). "X" at 1976, 1985, and 2005 (refers to reduction of blue-green algae or excess nutrients).
    - Chemical pollution begins in the 1890s, with the onset of the Industrial Revolution. "X" at 1945, 1948, 1977, and 1993.
    - Trash in the river begins in 1894. "X" at 1965, 1976,1989, 2005, 2006, and 2010.

SUGGESTED ADAPTATIONS:

- Teachers may prepare the timelines in advance for their students, or may assign students a sub-section of the total timeline or just one of the pollutants.
- Some teachers work with History or Social Studies teachers to encourage students to connect these moments in time with other historical events and trends.



Potomac River Watershed Timeline EXPLORATION

In addition to the above, many governmental or citizen actions have tried to address several, if not all, of these problems. An "X" may be placed on several lines for each of these years.

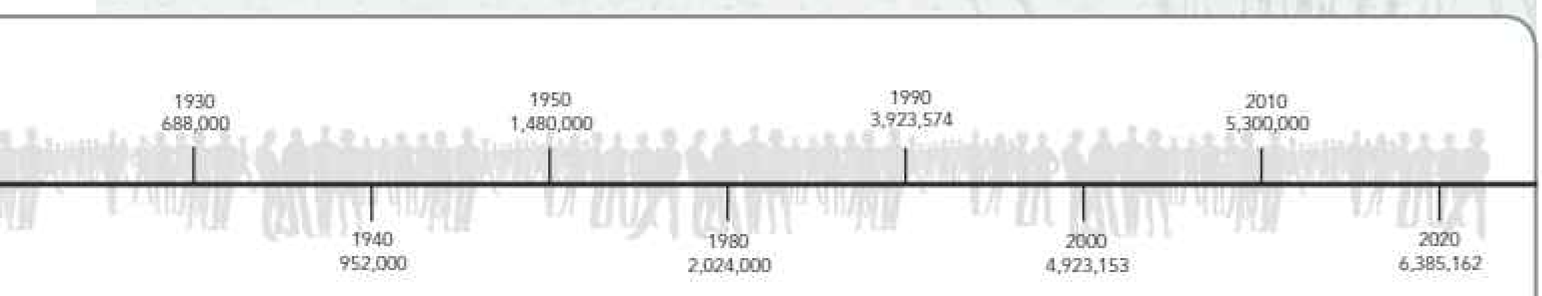
As students construct their timelines, they should come to realize that these problems are severe and ongoing. Students should be able to justify each decision, by referring to the History, as they draw their lines and mark their "X"s.

11. Which of these problems have been solved? Choose one of the problems to research and find out how severe this problem is today in the Potomac River. Try using current newspaper or magazine articles, or searching on the Internet.

None of these problems are completely solved, but many efforts have been and are being made to address them. In particular, federal legislation in the 1970s curtailed much point-source pollution; half the water bodies listed as impaired then have since been declared fishable and swimmable.

Suggested extensions for students:

- Start a bulletin board of current news articles relating to these problems.
- Assign individuals or small groups to research the details of a government action, such as the Maryland Water Quality Improvement Act of 1998.
- Assign individuals or small groups to learn about a citizen action group, and what members of the group do to preserve or protect the watershed.
- Ask students to look around their home neighborhoods to try to identify sources of any of these problems, such as silt fences around a new construction site that let sedimentation through, or trash on the street that will wash into the river through storm sewers.



Potomac River Watershed Timeline

EXPLORATION

POTOMAC TIMELINE[1]

This timeline represents an abbreviated history of water quality in the Potomac watershed (an area that stretches across parts of Maryland, Pennsylvania, Virginia and West Virginia as well as the District of Columbia).

Pre-1600 Native Americans hunt, fish, trap and plant their crops on small plots of land cleared by burning brush and trees. Large areas of forest surround their plots of land, buffering runoff into rivers even after severe rainstorms.

1608 Captain John Smith – the first European settler to fully explore the Chesapeake Bay and its tributaries – describes the Potomac as "... frequented by otters, beavers, martens, and sables. Neither better fish, more plenty, nor more variety for small fish had any of us ever seen in a place...".

1634 First Maryland colonists land near the mouth of the Potomac River. By the late 1600s, Prince George's County's 1,700 residents live primarily near streams. Less than two percent of the land is used for agriculture – primarily tobacco. Most of the land is still forest or meadow, resulting in little runoff or sediment.

1710 Colonists in Virginia commonly bury their trash. Holes are filled with building debris, broken glass, ceramics, oyster shells, animal bones and suits of armor.

1750 New towns are established downstream on Potomac as extensive logging, clearing of land for agriculture and housing, and more soil-destructive farming systems clog waterways with debris and sediment, making navigation further upstream impossible.

1810 The first sewer system in Washington, DC carries waste to the nearest stream.

1870 The Army Corps of Engineers dredges the Potomac River to keep it navigable.

1880s Industrial revolution ushers in intense pollution of skies and waterways. Factory smoke darkens the sky. Sediment and sewage is flowing into the water. Industrial waste and human waste are huge problems.

1890 Rock Creek Park created. Conservationist John Muir starts Sierra Club in 1892.

1894 United States Public Health Service reports "... at certain times of the year the [Potomac] river is so loaded with sediments as to be unfit for bathing as well as for drinking and cooking purposes. It contains fecal bacilli at all times." Disgusted by the sight of barge loads of garbage floating down the Potomac River from Washington, DC, citizens of Alexandria, VA sink the barges.

1 "Potomac Timeline." Interstate Commission on the Potomac River Basin. Web. 20 Sept. 2010. www.potomacriver.org/cms/index.php?option=com_content&view=article&id=96&catid=39&Itemid=57. Also, "Bay History – About the Bay – Chesapeake Bay Program." Chesapeake Bay Program — A Watershed Partnership. 23 Dec. 2009. Web. 20 Sept. 2010. www.chesapeakebay.net/history.html.

Potomac River Watershed Timeline

EXPLORATION

1902 President Theodore Roosevelt focuses national attention on protection of the nation's water and forest resources in his first State of the Union address.

1930 Washington Suburban Sanitary Commission (WSSC, Prince George's and Montgomery counties) connects its sewer system to DC's.

1932 Untreated wastes from Metro area population of 575,000 flow into Potomac. Heavy bacterial contamination forces river closing for swimming for 13 miles in lower Potomac. Low dissolved oxygen levels also endanger fisheries.

photo: Courtesy of DC Water.

1938 Blue Plains wastewater treatment plant in Washington DC is completed, with a capacity of 130 million gallons per day (mgd) primary treatment (heavy solids settle; lighter solids float to the surface and are discharged or subjected to secondary treatment).

1940 The Interstate Commission on the Potomac River Basin (ICPRB) is created to protect the Potomac River watershed.

1945 PA passes the nation's first law to place limits on acid-mine drainage pollution to streams.

1948 Congress enacts the first Federal Water Pollution Control Act, a 5-year plan to award grants to states to control pollution and build sewage treatment centers. The Act is extended and strengthened several times over the next decade.

Shenandoah River below Front Royal termed a "biological desert" due to industrial wastes.

1950 Post-World War II prosperity leads to increased spending by Americans, especially in consumer goods. Disposable containers are widely used.

1951 Low dissolved oxygen levels kill thousands of fish during the summer. Local media call attention to the Potomac's poor condition, describing it as "an open sewer." Wastes from raw and partially treated sewage of Washington, DC's population is double that of 1932.

1956 Several citizen watershed groups established.

1957 Public Health Service declares Potomac River unsafe for swimming. On average, 60 million cubic feet of sediment is deposited annually within the metropolitan DC section of the Potomac.

1959 Secondary treatment of wastewater added at Blue Plains.

Potomac River Watershed Timeline EXPLORATION

1960 Work begins on a plan to separate DC's combined sanitary and storm water sewers. Treatment plant in Westernport, MD, begins operation to clean up pollution in the North Branch Potomac.

1964 Several VA and MD suburban counties' sewage tied into DC's Blue Plains.

1965 Congress passes The Water Quality Act of 1965, establishing a Federal Water Pollution Control Agency and requiring water quality standards. President Lyndon B. Johnson calls the Potomac "a national disgrace," and sets clean–up goals.

1966 The Clean Water Restoration Act passes, increasing grants for research, state programs, and construction of wastewater treatment plants.

1970 The US Environmental Protection Agency (EPA) is established. Several jurisdictions pass erosion and sediment control laws.

1971 Water contact sports in the Potomac, Rock Creek, and the Anacostia River prohibited. Urban sediment is a major concern.

1972 The Federal Water Pollution Control Act Amendments initiate ground-breaking changes in water pollution control programs with a national goal of "swimmable-fishable" waters. The Act is later amended as the Clean Water Act in 1977 and 1987.

1976 The Resource Conservation and Recovery Act takes effect to deal comprehensively with solid waste issues.

There is a noticeable lack of blue-green algae mats that had covered the upper estuary a decade earlier. Pleasure boaters rediscover the Potomac; largemouth bass reappear.

1977 Congress passes Federal Surface Mining Control & Reclamation Act.

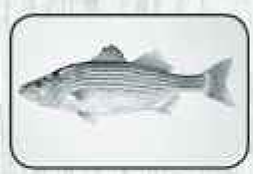
Clean Water Act strengthened to control toxic pollutants and to allow states to assume more regulatory responsibilities.

Mercury is discovered in sediments and fish in the Shenandoah River.

1980 Federal Superfund legislation takes effect, marking beginning of national effort to clean up abandoned hazardous waste sites.

1983 EPA completes its Chesapeake Bay Study. Several jurisdictions sign Chesapeake Bay Agreement calling for unified effort to improve the health of the Bay.

1985 MD initiates a phosphate ban and a fishing moratorium on fishing for striped bass.



Potomac River Watershed Timeline

EXPLORATION

1986 All major wastewater treatment plants in DC metro area achieve phosphorus removal. DC initiates a phosphate detergent ban.

Avtex Fibers – a rayon manufacturing plant on the Shenandoah River – is listed as an EPA Superfund site.

1987 Clean Water Act revised.

Multi-jurisdictional Anacostia Watershed Restoration Committee formed.

WV, MD agree to develop an acid-mine drainage abatement plan.

1989 Alice Ferguson Foundation starts first Potomac River Cleanup.

MD finds dioxin in North Branch fish. PCBs (polychlorinated biphenyls) are found in Shenandoah fish. PCBs and chlordane are found in DC fish.

1991 Anacostia River restoration action plan adopted.

1992 President George H.W. Bush declares 1992 the "Year of Clean Water."

1993 More than 400,000 gallons of diesel fuel from ruptured oil pipeline spills into a Northern Virginia tributary of the Potomac. Anacostia River deemed endangered and Anacostia considered a "region of concern" for chemical contaminants.

1997 WV initiates program to provide farmers with federal and state funds to implement water quality protection measures.

1998 Federal Clean Water Action Plan initiated; emphasizes watershed approach to restoring the nation's waters.

2002 Clean Water Act turns 30 and President George W. Bush declares 2002 the "Year of Clean Water."

2005 VA limits amount of nitrogen and phosphorous that large wastewater treatment plants are allowed to discharge.

AFF Watershed cleanup yields 217 tons of trash from 309 cleanup sites. 5,875 volunteers collect an average of 75 pounds of trash per individual.

2006 Chesapeake Bay watershed population hits 16.6 million.

First Potomac Watershed Summit convenes stakeholders from around the region to find innovative solutions, beyond community cleanups, to achieve a Trash Free Potomac.

2009 President Barack Obama signs Executive Order calling on the federal government to lead the effort to control pollution and protect wildlife habitats in the Chesapeake Bay region.

Federal farm bill funding directed to the Chesapeake Bay region to finance agricultural conservation practices that reduce pollution from farms. Annapolis, Md., becomes the first jurisdiction in the Chesapeake Bay watershed to ban phosphorus in lawn fertilizer.

Potomac River Watershed Timeline

2010 Anacostia River Cleanup and Protection Act takes effect, implementing a 5-cent fee on disposable plastic and paper bags. Anacostia River becomes second river in the nation to get a Total Maximum Daily Load (TMDL) for trash. Referred to as a "pollution diet," TMDL sets minimum levels of trash that must be removed from the river.

Potomac River Watershed Cleanup grows to 575 sites, 425 partners, and nearly 15,000 volunteers. Trash collected per volunteer drops for first time in 21 years.

Potomac River shows reduced nutrients and improved water clarity as a direct result of restoration efforts.

2014 The Chesapeake Bay Watershed Agreement is signed. This establishes goals and outcomes for Chesapeake Bay restoration across political boundaries. The Agreeement, includes the Bay, its tributaries and the lands that surround them.

2019

2020 July 8, 2019 and September 10, 2020 super storms dumped unprecedented amounts of rain in the Washington DC region prompting the National Weather Service to declare its first-ever flash flood emergency in the Washington DC area. The warming climate is affecting local weather patterns, storms are more intense and frequent and periods of drought are becoming longer.

The three warmest years on record in DC are 2012, 2017 and 2020.

The Chesapeake Bay Program commits to "equitable, just and inclusive engagement of all communities living throughout the watershed."

2023 The Potomac Conservancy Scores the Potomac River's heath a "B" grade, an improvement from a D + in 2007, C in 2016, and B- in 2020. Industrial pollution, wastewater effluence and agricultural runoff are in steady decline. Polluted urban runnoff from paved surfaces is growing. This carries street oils, lawn fertilizers, trash and diluted sewage directly in the stream.

2023 was the planets warmest year on record.

Massive system of tunnels are completed that prevent 98% of sewer overflows into the Anacostia River, from approximately 84 times per year to 2 times per year. This system also diverts 1000s of tons of trash coming through the sewer system. The Potomac River and Rock Creek are also slated for tunnels to be copleted by 2030.

2024 Alice Ferguson Foundation celebrates 70 years of providing watershed education along the Potomac

Color Me A Watershed

EXPLORATION

(Adapted from "Project WET Curriculum and Activity Guide." Permission to use this activity has been granted by The Watercourse and Council for Environmental Education.)

BACKGROUND INFORMATION:

In this activity, students will create maps to investigate changes in a watershed over the last 100 years. A watershed, or drainage basin, consists of the land from which all the water ultimately drains into a given waterway. In nature, surface water is captured by the soil (to become groundwater) and by vegetation. This surface water is slowly released into the closest body of water. The way land is used can have a significant impact on the region's water resources: an increase in impervious surfaces leads to increased volumes of runoff. Runoff brings pollutants – such as sediments, chemical residues, road salts, and fertilizers – into streams and rivers.

Maps are used by natural resource managers and policymakers to monitor land use changes that could contribute to increased amounts of runoff flowing into a river. Vast amounts of public and private time, energy, and money are invested in research projects to collect land use data. Monitored land use types include urban, agricultural, industrial, and transportation systems, and public lands.

Climate change will exacerbate the impacts of land use changes. The U.S Geological Survey reports an increase in stream flow in the United States since 1940, with particular increase in the mid-Atlantic region. The increases began suddenly around 1970, suggesting a shift to a new climatic regime. The future likely holds more short- and long-term variations in flow. More extremes in stream flow may mean more scouring of stream banks, and are likely caused by more extreme precipitation, which in turn causes more sediments to enter streams with runoff.

PREPARATION:

Gather colored pencils for each group in the required colors, and review coordinate grids. Review the location of the Potomac River watershed.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **What factors can affect runoff in a watershed?**

   Examples of factors that affect runoff are the amount of rainfall, how much of the land is covered by impervious surfaces, the number of plants growing there, and the slope of the land.

Goals:

- To explore the effects of population growth and land use on runoff in a typical watershed.
- To evaluate how changes in land use affect runoff.

Class Time:

90 minutes

Group Size:

Groups of 2-3 students.

Materials List for Each Group:

- Colored pencils: orange, red, yellow, brown, green, blue.
- Tables without answers.

Special Considerations:

- Students need to be able to find the Chesapeake Bay, the Potomac River, and the Anacostia River on a map.

  Maps of the Washington, D.C. area should be available so students can visualize their communities as part of the Potomac River watershed.
- Students also need to know the difference between the various land types: forests, grasses, residential, agricultural, and wetlands.
- You may need to review how to plot locations on a coordinate grid and how to calculate area in square kilometers.

Color Me A Watershed

EXPLORATION

2. **Think about what happens when rain falls on land with different types of ground cover. Rank the following from 1 (having the greatest runoff) to 4 (having the least runoff).**

   4 a grassy meadow

   2 a well-worn dirt path

   1 a concrete parking lot

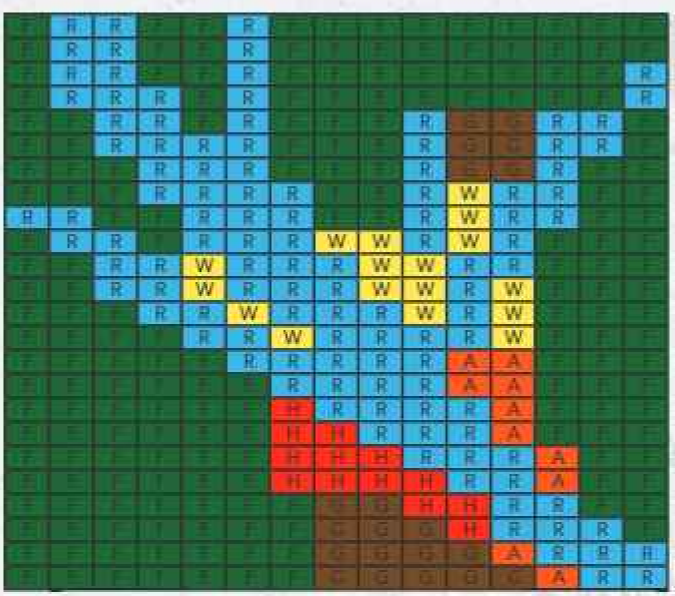
   3 a corn field

New Terms and Topics Introduced in this Activity:

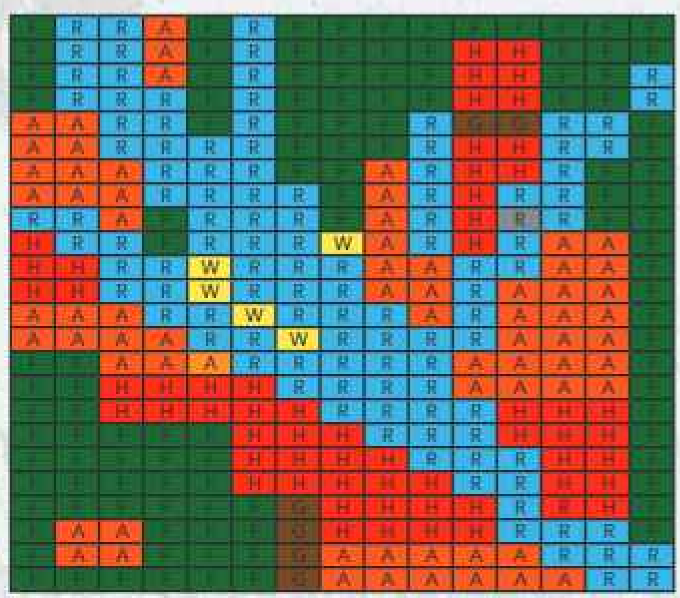
- Impervious surfaces
- Land usage
- Permeability

3. **Locate the map grids A & B. These maps represent an imaginary watershed and show changes in land use over 100 years. Each individual block is marked with a letter to indicate ground cover or land use (i.e., R= river, F= forest, A= agriculture, H= housing, W= wetland, G = grassy meadow). Color the blocks on both maps by using the following color code.**

Color Key	
River	Blue
Forest	Green
Agriculture	Orange
Housing	Red
Wetlands	Yellow
Grassy Meadow	Brown



100 YEARS AGO



PRESENT

Color Me A Watershed

EXPLORATION

4. **Assume each square on the map represents one square kilometer. How much total area is represented on each map?**

   15km x 24km = 360 km^2

5. **Determine how many square kilometers (km^2) each type of ground cover/land use occupies on the map.**

   Record the results in Table IV Ground Cover/Land Use. Calculate and record the percentage (%) that each type of ground cover occupies. Repeat these steps for Map B. See Table IV for answers.

6. **Compute change in % of total in Table IV Ground Cover/Land Use. Be certain to include a "+" to show an increase or " – " to indicate a decrease. The answers for "River" in Table IV have been completed as an example.**

   See Table IV below for answers.

TABLE IV: GROUND COVER/LAND USE

	Map A: 100 Years Ago		Map B: Present		
Ground Cover	Area (km^2)	% of Total	Area (km^2)	% of Total	Change in % of Total
River	111	30.8	111	30.8	0
Forest	189	52.5	111	30.8	- 21.7
Agriculture	10	2.8	69	19.2	+ 16.4
Housing	13	3.6	58	16.1	+ 12.5
Wetland	17	4.7	5	1.4	- 3.3
Grassy Meadow	20	5.6	6	1.7	- 3.9

7. **Refer to Table IV and your colored maps to answer questions a and b.**

   a. **Which categories of ground cover/land use showed the greatest percent increase?**

      Agriculture and Housing

   b. **Describe where these changes in ground cover/land use occurred in relation to the river.**

      The three greatest % changes occurred in forests, agriculture, and housing. Forests decreased while agriculture and housing increased. As population increased, more homes and more food were required. Most of the changes took place near the stream because people liked or needed to live near water.

8. **If all rain is absorbed when it hits the ground, there is no runoff. If no rain is absorbed because it is blocked by impervious surfaces such as asphalt roads, all the rain becomes runoff. These are two extremes to emphasize how runoff is created. Answer the following question after reading the section on erosion on page 39 of the Resources. Do you think a watershed is healthier if rain is absorbed into earth or runs off into the nearest waterway? Explain.**

   A watershed is healthier if rain is absorbed into the ground to become groundwater or be filtered before entering water bodies. Rain that soaks in supports plant growth and the animals that eat those plants. Humans need water, too. Whatever doesn't soak in runs off and erodes the land as it does so. The more runoff there is, the more sedimentation occurs, including the loss of topsoil. With less topsoil in place, fewer plants grow, so erosion continues to increase. The downward spiral continues until the ecosystem collapses.

9. **Find out if the volume of runoff changed in this imaginary watershed over the 100-year period. Assume that during one rainfall 12,500,000 m^3 of rain fell evenly over the entire watershed on map A, and the same amount of rain fell evenly on the watershed on map B. To find out how the total runoff changed because of the changes in land use, follow these steps.**

   a. **How much rain fell on each block?**

      34,722.222 m^3/km^2

   b. **Multiply the km^2 of each ground cover/land use (from Table IV) by the amount of rain that fell on each block. This will tell how much rain fell on each category of ground cover. Record these totals in Table V.**

TABLE V: VOLUME OF RAIN (M^3)

Ground Cover/Land Use	Map A: 100 Years Ago	Map B: Present
Forest	6,562,500	3,854,167
Agriculture	347,222	2,395,833
Housing	451,389	2,013,889
Wetland	590,278	173,611
Grassy meadow	694,444	208,333

   c. **Table V shows how much rain runs off each category of ground cover/land use. Complete both columns in the table by multiplying the volumes you recorded in Table V by the percent runoff listed in Table VI for each category. Then total each column.**

TABLE VI: VOLUME OF RUNOFF (M^3)

Ground Cover and Land Use	Percent Runoff	Map A: 100 Years Ago	Map B: Present
Forest	20%	1,312,500	770,833
Agriculture	30%	104,167	718,750
Housing	90%	406,250	1,812,500
Wetlands	5%	29,514	8,681
Grassy meadow	10%	69,444	20,833
	Total runoff	1,921,875	3,331,597
	Difference in runoff	+1,409,722	

Color Me A Watershed

EXPLORATION

d. Compute the change in total runoff from the watershed over 100 years. Be certain to include a "+" to show an increase or "–" to indicate a decrease.

10. In previous activities, you have seen that land use affects runoff, and runoff affects water quality. Describe how the water quality has probably changed.

The water is probably more polluted, with increased turbidity and sedimentation. Eutrophication has probably occurred.

SUGGESTED ADAPTATIONS:

- Discuss land use practices in the community and how they may affect water discharge in the watershed.
- Take students around the school and community, and note areas that contribute to or reduce storm runoff. (For example, parking lots, paved roads and sidewalks promote runoff; ponds, trees, and other plants capture water.)

Plan Wisely for Your Students' Field Study

ENGAGEMENT

BACKGROUND INFORMATION:

It is crucial that all students be prepared for the field study in the park. For many students, working outdoors will be an unusual and challenging experience. You should review the information in this section carefully with your students to help them prepare mentally for the field study, and to ensure that they have the appropriate dress and supplies to be comfortable in the park. You may have to review this information several times before the park field study to be sure all students understand the required preparations and plan well for their visit. Listening to the weather and developing a what-to-wear list for the day is a great homework assignment or class discussion in advance of the field study. Some teachers do a dry run a few days in advance of the field study by having their students come to school wearing their field study clothes with their backpacks packed as if for the field study.

Before the site visit, complete the activities in this module to ensure that all students understand the concept of a watershed (see introduction for hands-on lessons). Also, review the directions for data collection and completion of Table VIII: Characteristics for Stream Habitat Assessment. Students can read the resources section that provides the information they will use in the park.

The AFF educator and National Park Service ranger will have all the other supplies for the field study activities.

PARK INFORMATION:

Students can review information about the park and its history on the Bridging the Watershed website at fergusonfoundation.org.

THINGS TO BRING:

- There will be no place to buy food. Students must bring a bag lunch and plenty to drink, preferably water. For students on a school lunch plan, let the cafeteria manager know about the field trip a few days in advance to ensure that a bagged lunch will be available.
- The hotter the weather, the more students should bring to drink. Have students pack their lunch and drinks in a backpack or bag that they can easily carry into and out of the park study site.
- Keeping in the ecology-minded spirit, suggest that students make their lunch as trash free as possible. Some areas and parks do not have trash cans to encourage stewardship behaviors. What is packed in must be packed out.
- Make sure that students bring sunscreen and insect repellent.

Goal:

To help students plan and prepare for their field study in a local national park.

Plan Wisely for Your Students' Field Study

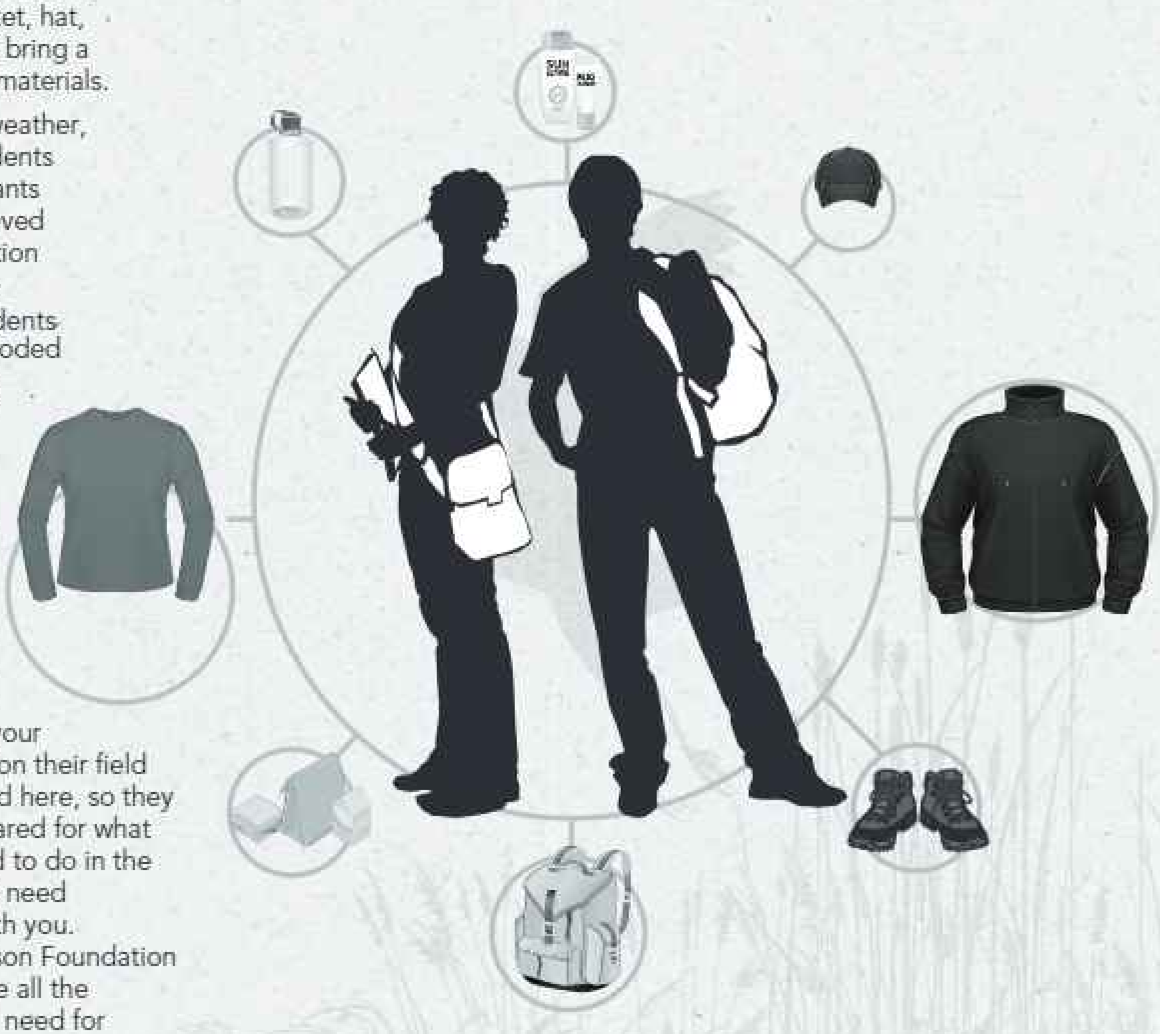
ENGAGEMENT

PARK STEWARDSHIP:

- Remind students that collecting of any type is not permitted.
- Remind students to take only photographs and leave only footprints

TIPS ABOUT CLOTHING:

- Students should wear comfortable clothing that allows them to easily move, hike, bend, and climb. Students may have to gather data in a wet and muddy environment, so they should choose clothes they don't mind getting wet and dirty. If students are going in the water, it is a good idea to bring an extra pair of socks.
- Dress for the weather. In cool weather, encourage students to wear layers of clothing to keep them warm in the early morning, but that they can remove later in the day or while working. If the forecast calls for possible rain, students should wear a waterproof jacket, hat, and shoes, and bring a plastic bag for materials.
- Even in warm weather, encourage students to wear long pants and a long-sleeved shirt for protection from poison ivy and briers. Students may be in a wooded area or walking through tall grass.



The data sheets your students will use on their field study are included here, so they can be well-prepared for what they will be asked to do in the park. You will not need to bring these with you. Your Alice Ferguson Foundation educator will have all the materials you will need for your field study.

Plan Wisely for Your Students' Field Study

ENGAGEMENT

Bridging the Watershed

Don't Get Sedimental Datasheet

Date: ______

Teacher: ______

Park: ______ Study Site: ______

Park Rangers & Educators: (one per row) | Group Members: (one per row)

Latitude: North ____°____'____" Longitude: West ____°____'____"

Why is it important to know the latitude and longitude?

	Yesterday	Today
Air Temperature	____°C	____°C
Cloud Cover	☐ Clear ☐ Partly Cloudy ☐ Cloudy	☐ Clear ☐ Partly Cloudy ☐ Cloudy
Precipitation	☐ None ☐ Rain ☐ Other	☐ None ☐ Rain ☐ Other

How could weather affect today's field study?

Water Color ______ Water Odor ______ Water Temperature ____°C

Stream Speed:

Trial 1 ______ Seconds

Trial 2 ______ Seconds

Trial 3 ______ Seconds

Average ______ Seconds (Add all 3 Trials and divide by 3)

Stream Speed measured with digital probe: ______ ft/s

Use the average time from above in the calculation below to determine average stream speed

10m / ____ [average time]= ______ meters/second

Because we test speed only at the surface of the stream, we use a 'fudge factor' of 0.8 to adjust for an overall stream speed. Use the average speed from above to find the overall stream speed:

Average Speed x 0.8 (fudge factor) = ______ meters/second

Sketch the study site, showing all details that affect your field study:

Plan Wisely for Your Students' Field Study

ENGAGEMENT

Soil Permeability: Seconds   Turbidity: JTU's

Characteristics for Stream Habitat Assessment

	Excellent Score: 4	Good Score: 3	Fair Score: 2	Poor Score: 1	Site Score
Verge Vegetation	vegetation present, canopy intact	vegetation and canopy nearly intact	vegetation disturbed	cleared land or urban development	
Bank Vegetation	vegetaton in undisturbed state	vegetation slightly disturbed	vegetation moderately disturbed	vegetation severely disturbed	
% Bare Soil on Bank	0 - 10%	11 - 40%	41 - 80%	81 - 100%	
Bank Erosion	stable, no sign of erosion	very occasional local erosion	some erosion evident	severe bank failure; extensive cracking and fall-ins	
Bank Slumping and Movement	no movement	slight movement on bank	moderate bank collapses	severe bank failure; extensive cracking and fall-ins	
Bends and Riffles	Bends present; 5 - 10 riffles in 10 m; some snags	Bends present; 1 - 4 riffles in 10 m	occasional bend; 1 -2 riffles in 50m; few snags	straight channel; riffles/pools absent; no snags	
Turbidity (JTUs)	0 - 10	11 - 40	41 - 150	> 150	
Aquatic Vegetation	little vegetation - uncluttered look; fairly small numbers of many different kinds of plants	moderate amounts of vegetation	cluttered, weedy conditions; vegetation sometimes luxurious and green; seasonal algal blooms	choked, weedy conditions; heavy algal blooms or no vegetation at all	
Sediment Deposition	less than 20% of stream bottom affected by extensive sediment deposition; minor accumulation of fine and coarse material at snags; little or no enlargement of islands or point bars	20 - 50% of stream bottom affected by extensive sediment deposition; moderate accumulation; substantial sediment movement during major storms; some new increase in bar formation	50 - 80% of stream bottom affected by extensive sediment deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movements during storm events	> 80% of stream bottom affected by extensive sediment deposition; heavy deposits; mud, silt and/or sand in pools; pools almost absent due to deposition	
				Total Score	

Stream Habitat Rating		
32-36	Excellent	natural or virtually natural state
23-31	Good	some alteration from natural state
14-22	Fair	significant alteration from natural state
0-13	Poor	very degraded habitat

Habitat Rating	

Assessing Stream Habitat

EXPLORATION

BACKGROUND INFORMATION:

In this field study, students will collect data on stream characteristics that indicate the effects of runoff on the stream. Bear in mind that erosion is a natural process that alters the face of Earth over time. For our purposes here, the field sheet and assessment criteria are standard tools for assessing stream health. This information will be used in a later exercise to prepare a report using the data collected in the park.

The Alice Ferguson Foundation educator will facilitate this exploration and provide all materials needed for field investigations.

Goal:

To assess the impact of sedimentation on the health of a stream habitat in a national park.

Class Time:

The field study will be completed in a single, 3-5 hour visit to a national park.

Group Size:

3-5 students per group

Materials

Your AFF educator will have everything your students will need for the field study.

Data Analysis

EXPLANATION

BACKGROUND INFORMATION:

In this activity, students will prepare a summary report assessing the stream habitat in the park they visited. Using the data they collected, each group will write a report describing the general health and conditions of the stream, focusing primarily on the effects of runoff. Other students, conducting similar tests, will be able to compare results.

Explain that each group compile a report, just as they would after a laboratory activity in the classroom. When they have completed their written report, each group will use their evaluation form from the student pages to assess their own work. Remind students that their efforts can help to better understand the environment, and are valuable contributions to their communities' knowledge.

Goal:

To compile class data in order to rate the effects of sedimentation and runoff on the health of the stream habitat.

Class Time:

90 minutes

Group Size:

This activity will be done in the groups that worked together in the park.

Materials List for Each Group:

- Computer with Internet access

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **Compare your data with the data from the other group(s).**

   In the park, each group gathered data about the stream habitat and recorded it on their datasheet. Record your group's data on Table VII: Class Data for Color, Odor, Soil Permeability, and Stream Speed and Table VIII: Class Data for Stream Habitat Assessment to determine the class average or consensus for each of the stream characteristics.

2. **Rate the stream habitat.**

3. **Each group will use the class data to prepare a report. Begin your report with the name of the park you visited, the date of your visit, and the name of the module. Define the study area and weather conditions using data from the first page of your group's data sheet.**

4. **In addition to using the rating chart, be sure to examine and include the other factors that indicate stream health such as apparent color, odor, soil permeability and stream speed from Table VII.**

Data Analysis

EXPLANATION

5. **The Performance List follows. Use this list to evaluate your group's final report, as well as your group's data collection efforts in the park.**

Using Performance Lists to Assess Student Work:

Performance lists are often used to assess and evaluate student work. Performance lists consist of criteria that define the essential elements of the performance and /or product and are used to "paint" the target for both students and teachers. Because of the design and intent of performance lists, feedback to students is analytical in that both strengths and weaknesses of the performance can be delineated. In the classroom, performance lists have proven to be the easiest assessment tools for the teacher to design and for the student to use. Typically, they are the first and most important steps toward building other assessment tools, such as holistic and analytical rubrics.

The essential performance criteria provided in the performance list are defined in clear, concise, descriptive, and unambiguous language so that all audiences understand the target. Once the criteria have been defined, the teacher can "weigh" the various elements of the performance by assigning different point values. This serves to draw attention to the most important criteria for a particular performance. For example, suppose the teacher decides to assign a scale of 0–5 points to Element #1, which states, "All group data are entered, and the stream habitat is rated accurately." Element #1 clearly defines one essential component of the performance and can be scored anywhere between 0 and 5 points. Element #2 states,"All class data are entered, and the stream habitat is rated accurately by average or consensus." By contrast, this task is assigned a 0 -10 point value. Obviously, Element #2 receives greater emphasis for this particular performance. Thus, the various elements of the performance can be "weighted" depending upon the goals of the teacher. Points for all criteria can be totaled at the end and be used for student revision and /or assignment of grades.

TABLE VII: CHARACTERISTICS FOR STREAM HABITAT ASSESSMENT

Apparent Color of Water = light yellow	Odor of Water = slightly fishy			
Soil Permeability = 42 seconds	Turbidity = 20 JTUs or 30 centimeters			
Time for object to travel 10 meters:	Trial 1 = 3.1 sec	Trial 2 = 3.5 sec	Trial 3 = 3.3 sec	Average = 3.3 sec
Overall Stream Speed = (10 meters/ 3.3 sec) x .8 = 2.4 m/sec				

Data Analysis

EXPLANATION

TABLE VIII: FIELD SHEET EXAMPLE

Characteristic	Score 4	Score 3	Score 2	Score 1	Site Score
Verge Vegetation	Vegetation present and canopy intact	Vegetation and canopy nearly intact	Vegetation disturbed	Cleared land or urban development	2
Bank Vegetation	Vegetation in undisturbed state	Vegetation slightly disturbed	Vegetation moderately disturbed	Vegetation severely disturbed	3
% Bare Soil On Bank	0 - 10%	11 - 40%	41 - 80%	81 - 100%	2
Bank Erosion	Stable; little or no sign of erosion	Occasional local erosion	Some erosion evident	Severe bank failure; extensive cracking and fall-ins	3
Bank Slumping and Movement	No apparent movement	Slight movement on the bank	Moderate bank collapses	Severe bank failure; extensive cracking & fall-ins	3
Bends and Riffles	Bends present, 5-10 riffles in 10 meters, many snags	Bends present, 1-4 riffles in 10 meters, some snags	Occasional bend, 1-2 riffles in 50 meters, few snags	Straight channel, riffles/pools absent, no snags	2
Turbidity (JTUs)	0 - 10	11 - 40	41 - 150	>150	3
Aquatic Vegetation	Little vegetation – uncluttered look; fairly small numbers of many different kinds of plants	Moderate amounts of vegetation	Cluttered, weedy conditions; vegetation sometimes luxurious and green; seasonal algal blooms	Choked, weedy conditions, heavy algal blooms or no vegetation at all	3
Sediment Deposition	Bedrock exposed with less than 20% sediment; minor accumulation of fine and coarse material at snags, and little or no enlargement of islands or point bars	21-50% of stream bottom affected by extensive sediment deposition; moderate accumulation; substantial sediment movement during major storms; some new increase in bar formation	51-80% of stream bottom affected by extensive sediment deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events	>80% of stream bottom affected by extensive sediment deposition; heavy deposits; mud, silt, and/or sand in pools almost absent due to deposition	3
				Total Score	24

Lower levels of sedimentation

↕

Higher levels of sedimentation

Stream Habitat Rating
36 - 32 = Excellent
31 - 23 = Good
22 - 14 = Fair
13 - 0 = Poor

Note: The lower the stream habitat rating, the higher the level of sedimentation.

Performance List

EVALUATION

Group Members ____________________ Date ____________

Performance Criteria	Assessment		
	Points	Group	Teacher
1 All group data are entered, and the stream habitat is rated accurately.			
2 All class data are entered, and the stream habitat is rated accurately by average or consensus.			
3 The report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data, a descriptive assessment of the health of the stream is included.			
5 Individual stream characteristics that were significant are noted and possible reasons for them are proposed.			
6 The summary is clear and concise, and accurately reflects the findings of the study.			
7 Scientific terminology and concepts are accurately explained and applied to illustrate major points of the report.			
8 Visual aids (photographs, charts, graphs, and drawings, etc.) enhance understanding of the text.			
9 Visuals are clearly titled, labeled, and referenced within the text.			
10 Language used in the report is purposeful, descriptive, and appropriate for the intended audience.			
Total			

Teacher Comments:

Great Terrain Robbery

EVALUATION

BACKGROUND INFORMATION

Soil as a Natural Resource

Soil can be considered a non-renewable natural resource because the formation of new soil is a very slow process. In temperate areas like the Chesapeake Bay watershed, it takes two hundred to one thousand years, depending on soil and climate type, to renew just one vertical inch of topsoil.

What is the Problem?

During farming and building activities, the plant material that covers, protects and holds the soil in place is disrupted, removed, or paved. When soil is left uncovered, it is more easily moved by wind and water, which is called erosion. Erosion often moves soil into creeks, rivers, and bays, a process called sedimentation, which decreases water quality and disrupts aquatic life. Worldwide, soil is eroding on farmland at seven to two hundred times the natural rate of soil renewal.

As more land is covered by impermeable surfaces such as pavement or asphalt, water cannot soak into the soil and runoff increases. Water moves more quickly over impermeable surfaces, and this fast runoff has more power to carry sediments, pollutants, and trash into the nearest waterway.

One approach to manage runoff is Low Impact Development (LID). LID works with nature to manage stormwater as close to its source as possible. LID aims to minimize imperviousness by preserving and re-creating natural landscape features, and site drainage that treats stormwater as a resource rather than a waste product. There are many LID practices that achieve this goal, such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions.

PROCEDURE, QUESTIONS AND POSSIBLE RESPONSES:

Follow the steps below to conduct the activity. Sentences in bold are suggestions for what teachers might say to students. Items in italics are possible student answers to questions.

1. **Prepare 5 bins of the same size for each group of 3-4 students, as depicted in the Experiment Set-Up Photo. The bins should each**

Goal:

Explain the effect of land use on runoff, erosion, and water quality.

Classtime:

1 period for initial trials; 1-2 periods for group bin designs and tests.

Group Size:

3-4 students

Materials List for Each Group

- 6 dishpans notched in one end, with spouts attached (see the photo of the experiment setup below)
- Soil for all the bins (the same amount and type)
- Soil cover materials: compacted soil, mulch, grass sod, asphalt shingles or plastic sheeting (something impermeable)
- One watering can per dishpan of soil (same size and type)
- 1-liter measuring containers
- A large-mouthed collection vessel for the runoff from each dishpan – these should be clear-colored and identical in size and shape
- A prop for each dishpan (2x4's work well). All the bins need to be at the same slope
- Turbidity test kit

have the same amount and type of soil and volume of water added (constants in the experiment), but vary in the surface covering (independent variable).

The soil coverings for the five bins should be:

a. Mulch

b. Grass sod

c. Compacted soil

d. Asphalt shingles or plastic wrap (something impermeable)

e. No cover

2. **Place prepared soil bins in a central location so all students can view the surfaces. Bins should all be raised at the back (the end away from the runoff spout) the same amount, so that the slope is the same for each bin.**

3. **Ask "Where have you seen real life examples of ground that looks like each of these bins?"**

   Answers will vary but may include:

   - *Mulch is found on flower beds, gardens, new road cuts, lawns, and playgrounds.*
   - *Grass sod is found in lawns, parks, roadsides, school yards, and playing fields.*
   - *Compacted soils are found in many of those places after some wear and tear.*
   - *Exposed soil is seen on farms/gardens before crops are planted, next to roads, under playground swings, and at construction sites.*
   - *Impermeable surfaces are found on roofs, sidewalks, cement areas, roads, and parking lots.*

4. **"Why is soil important to us?"**

   Soil is needed for food production, used for building surfaces, provides homes for animals, supports plants, etc.

5. **"We are going to conduct an experiment about water runoff and soil erosion. These soil bins are models to demonstrate what happens to different land surfaces when it rains."**

6. **"What are the parts of a well-designed experiment?"** Use the table below to lead students to identify the parts of the experimental design, including repetition. Repetition is acheived by having multiple groups run the same experiment. Share results between class periods to increase repetition.

Great Terrain Robbery

For this Experiment the...	Is...
Independent Variable	Soil Cover
Dependent Variable	• Amount of Runoff • Clarity of Runoff • Turbidity of Runoff
Constants	• Bin size, shape, material, slope • Soil amount and type • Water amount, type, and temperature • Watering can/applicator type • Water application (speed, height, same start time) • Runoff collection jar type, size, shape

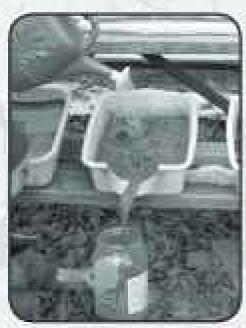
7. **"We are going to model a rainstorm and catch the runoff in the jars. The jars represent the river."**

8. **"We need to make some hypotheses before we run our experiment."**
   Ask students the following questions to formulate hypotheses. Students can disagree.
   "Which land surface will have the most runoff?"
   "Which land surface will have the least runoff?"
   "Which land surface will have the most erosion?"
   "Which land surface will have the least amount of erosion?"

9. **Student jobs may include:**
   - Measuring water
   - Pouring water
   - Catching runoff
   - Timing runoff

10. **Ensure that students pour water at the same rate from the same height.**






Great Terrain Robbery

EVALUATION

11. **Direct students to make observations about runoff and erosion on each land type.**

    "Which bin had the most runoff?" Impervious surface (measured by the volume of water collected in the runoff collection jar).

    "Which bin had the least runoff?" Grass sod.

    "Which bin had the most erosion, as demonstrated by water clarity?" Uncovered soil.

    "Which bin had the least erosion, as demonstrated by water clarity?" Grass sod.

12. **"So how do our results compare with our hypotheses?"**

13. Now each group gets one more bin of soil. **"Imagine you have just inherited this land and enough money to develop it however you'd like. Everyone needs at least one structure for housing a family of at least four on their land, and any other features you wish. We will compare them for the amount of runoff, level of turbidity, and clarity of water. Your goal is to have the lowest combined score on all those parameters."** You may want to read the resource section about different methods of low impact development. **"Since we will be testing these (that is, pouring water over them), you must also hand in a sketch that shows an aerial view and a profile of the bin, which highlights materials you've chosen. Also include a one-page explanation of why you chose these features, materials, and arrangements."**

14. When students have completed their designs, invite a representative of each group to explain the design. Then do the same trial with each group's bin at the same time to compare the results.

Student Action Project: Take Action!

ELABORATION

BACKGROUND INFORMATION:

Students have looked at the problems caused by pollution in the Potomac River watershed. Recognizing a problem is the first step to solving it. The next step is to take what they've learned, and apply that knowledge at the local level in the community.

During the field study in the park, students investigated a portion of their local watershed. This module and the field experience in the park were designed to create a Meaningful Watershed Educational Experience (MWEE).The MWEE process is student led with project-based learning. Inspiring stewardship through student action is the last step for a successful MWEE. The choices they make about how to interact with their environment in their watershed make a long-term difference, not only to the area in which they live, but also to the watershed as a whole.

TAKE ACTION!

Visit our Resource Library at fergusonfoundation.org/resources on the Ferguson Foundation website to view different types of action projects a student-led MWEE can be designed around. We provide some step-by-step instructions, but students provide the inspiration and execution.

To check for correct math, the adjusted "Total" should be a greater number than the raw "Total."

Goals:

- To increase awareness of the need for individual environmental action.
- To act locally and get involved in a service project.

What Your Class Can Do:

When students are ready to take the challenge, there are many great ways they can get involved. The first step is to head to the Resource Library at the Ferguson Foundation website to check out potential student-led action projects.

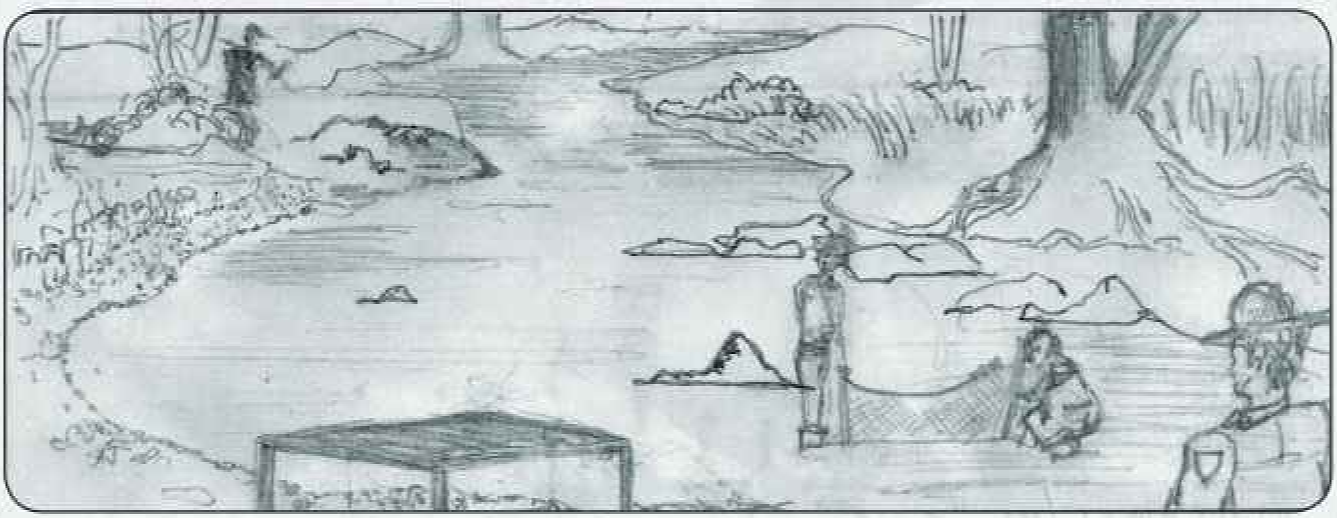
Resources

Stream Study

Aquatic ecosystems cannot be studied in isolation but must be viewed in relation to the surrounding area. The physical characteristics, or abiotic factors, of a stream are important in determining which organisms live there. One of the most important characteristics of any stream is its water speed. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity, and lower overall productivity. Speed will vary in different portions of the stream, such as rapids, riffles, pools, or on the inner or outer edges of a bend.

Overall biological characteristics of the stream are also significant because plants and animals living near the stream may alter the stream environment. The runoff from a nearby barnyard may increase the nutrients in a stream. Trees on the stream bank may shade the stream and lower the temperature during the day. Leaves and branches falling into the water from bank vegetation may serve as food for aquatic organisms. These three examples illustrate just a few of the biological influences that may affect the stream you are studying.

As you begin your study, locate your stream on a topographical map. Determine the stream's source and where it joins with a larger body of water. Sketch the study site as it appears from overhead and make notes to describe the area. The sketch and description will help you understand how land around the stream is used and may include such things as sources of runoff, the amount and variety of plant life present, types of animals present, human impact on the area, and any sources of pollution.



Effects of Pollutants on the River

TYPES OF POLLUTION

There are two basic types of pollution: point source pollution and nonpoint source pollution. **Point source pollution** comes from an identifiable source such as a pipe from a sewage treatment plant, a factory or a power plant. Wastewater from these sources can contain toxic chemicals, nutrients such as phosphates and nitrates, and other pollutants. If we know where pollution is coming from, we know who should be responsible for cleaning it up. There are fairly good pollution removal technologies available today as well as better laws regulating wastes from manufacturing and power plants. Because of this, point source pollution is much easier to control than nonpoint source pollution.

Nonpoint source pollution originates from a source that is not easy to identify or from multiple sources. Obviously, these pollutants are much more difficult to measure and control. Nonpoint source pollution is sometimes called "runoff pollution" because much of it is washed off large areas of land by rain. It can include substances such as:

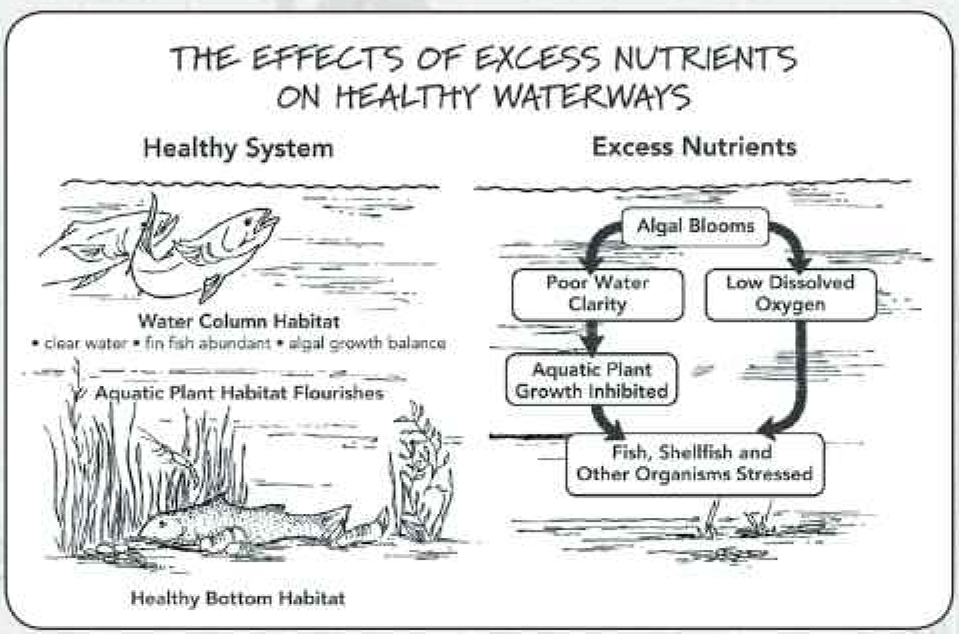
- fertilizers, pesticides, and other toxic chemicals from lawns and farmland;
- oil, grease, and litter from streets and parking lots;
- soil eroded from construction sites;
- air pollutants brought to the surface in precipitation.

Nonpoint source pollutants have a much greater impact on life in the Potomac River than do point source pollutants.

NITRATES AND PHOSPHATES

Nitrogen and phosphorous are two primary nutrients that are essential for plants and animals, including humans. They are common elements in nature with nitrogen gas making up the majority of our atmosphere. Phosphorous also occurs naturally in some rocks. These elemental forms, however, are useless to most living things, which can only process them when they combine with oxygen to form nitrates and phosphates. Human sewage, farm animal manure, and commercial plant fertilizers used on lawns and farm fields are all heavy sources of nitrate and phosphates.

These nutrients are two of the primary pollutants in the Chesapeake Bay. When the Bay receives an excess of nitrates and phosphates, the ecosystem gets out of balance and the entire food web is disrupted. It begins when single-celled plants called algae – an essential first link in the aquatic food

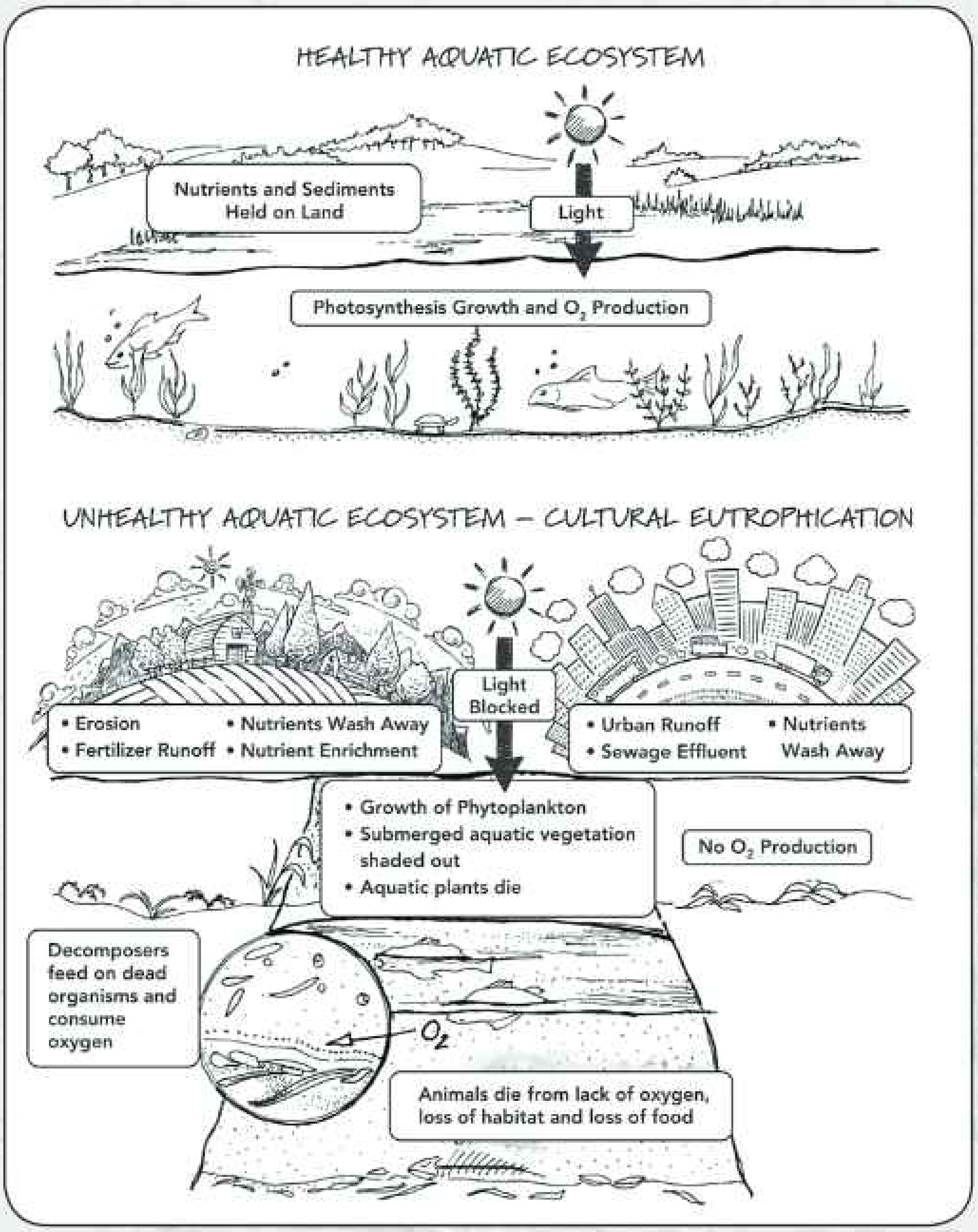


Resources

web – grow excessively because of too many nutrients in the Bay. Such "blooms," or population explosions, of algae cause the color of the water to become cloudy brown or green. This results in two major problems for other types of aquatic life. First, these algal blooms block sunlight from beds of submerged aquatic vegetation (SAV) that normally provide shelter, food, and oxygen for aquatic animals. SAVs die when light is reduced. Secondly, after the algae bloom, they die, sink to the bottom, and decay. The bacteria that break down, or decompose, the dead algae use large amounts of oxygen in the breakdown process. This further reduces the dissolved oxygen available near the bottom, and many types of fish, shellfish, crabs, and other aquatic life are harmed or even killed.

EUTROPHICATION

The literal meaning of **eutrophication** is "well-nourished." When it occurs slowly over hundreds of years, it is a natural step in the development of aquatic ecosystems. Waterways are rocky and devoid of life at the start, largely because plants are the basis of all food webs, and these new waterways lack soil for growing plants. Without many plants, there is low species diversity. As time goes by and the few plants there were die and decompose, or as flowing water brings nutrients and sediments into the waterway, soil accumulates and plant life flourishes. Plants provide food, shelter, and oxygen for a variety of animals, so diversity increases gradually. As long as the process of increasing available nutrients occurs slowly, balance is maintained.



When eutrophication is caused by sudden over-enrichment of nutrients in waterways, accelerated growth of algae and higher forms of plant life seriously disrupt the ecosystem. This type of eutrophication is sometimes called "**cultural eutrophication**" to distinguish it from the natural process of eutrophication. Damage to the ecosystem occurs because a diverse ecosystem based on SAV is converted to a simpler one based on phytoplankton and emergent vegetation. This causes many organisms to die. A eutrophic body of water is characterized by nutrient-rich water that supports an abundant growth of aquatic plants at and near the surface. Near the bottom, plants die because light is blocked. Animals that need those plants for food, shelter, or oxygen can no longer survive. Dissolved oxygen is high at the surface due to photosynthesis of the algae but is zero or near zero closer to the bottom because of the disappearance of rooted plants and the use of oxygen by decomposers. As a result, detritus accumulates on the bottom.

Cultural eutrophication can have both temporary and permanent effects on aquatic ecosystems because it significantly reduces biodiversity (a measure of the number of different species in a given area). Animals that depend even partly on the plants that die off, or upon the dissolved oxygen they produce, will be at a significant survival disadvantage.

Impacts of Cultural Eutrophication

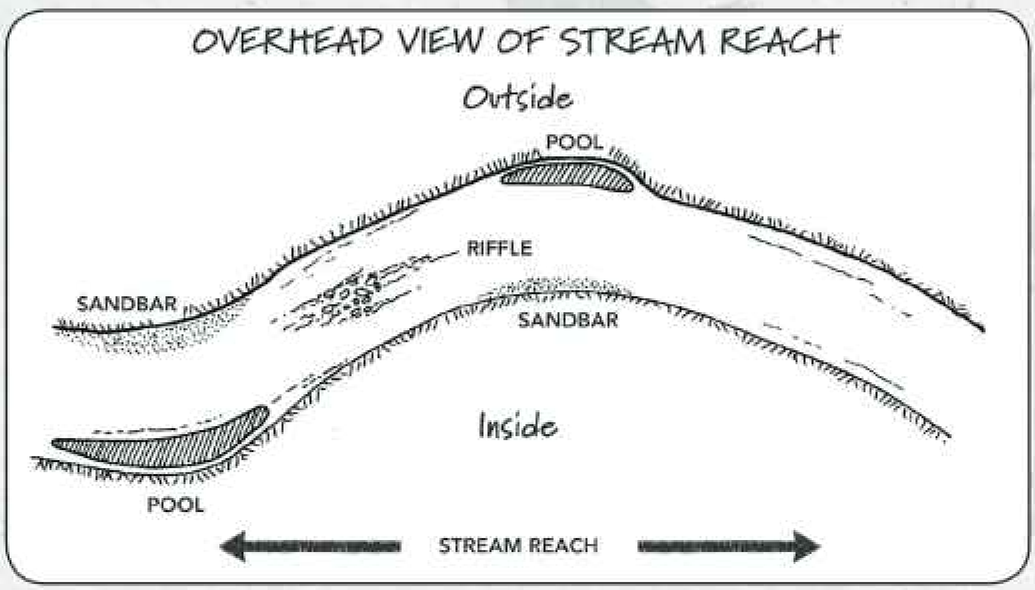
Eutrophication is a natural cycle that should take thousands of years. Cultural eutrophication, what humans cause, is so accelerated that it can occur in years or months, potentially causing the death of an entire ecosystem. The first sign of cultural eutrophication is usually an algal bloom that turns the water pea-soup green. Aquatic plants that normally grow in shallow waters become very dense. Swimming and boating may become impossible. While the nutrients last, rapid reproduction of algae and macroscopic plants continues. When the nutrients are used up, many of the excess plants and algae die.

Riffles, Pools, and Bends

Rocks and debris in a stream may create shallow areas. Water rushes over these shallow areas to form an area of rapids with turbulent flow, called a **riffle**. Riffles aerate (add oxygen to) the water and provide habitat for many invertebrates.

A **pool** is a deeper area of water that is quiet and often has no visible flow. Pools provide deeper areas for fish and other larger aquatic organisms. Streams that have many pools and riffles are able to support more life and a greater variety of species than streams that do not.

A **bend** is a change in the direction of the stream channel and the flow of water. Larger, slow-flowing rivers usually have more bends that can provide different habitats. The cutting action of the water at bends provides regions of varying depth and water velocity. Frequently, there is erosion of the bank on the outside of a bend and sediment deposition on the inside of the bend.

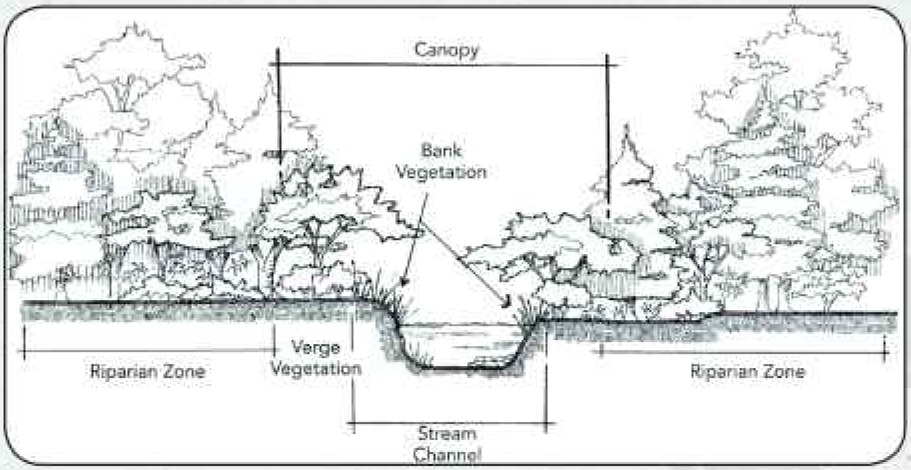


Land Vegetation

The condition of **vegetation** (e.g., trees, shrubs, grasses) around a stream is a good indication of the health of the aquatic environment. Vegetation provides a natural buffer against erosion and prevents transport of sediments into streams. When vegetation around a stream is degraded, there is less protection for the stream. Deterioration of water quality and habitat for aquatic plants and animals may occur.

A **riparian** buffer area refers to land adjacent to streams, rivers, or water bodies that directly affects and is affected by the water. Trees, shrubs, and other types of vegetation grow in riparian buffer areas along waterways. These plants prefer moist to very wet soil and can withstand the disturbance of water flowing over and around them.

The riparian area includes bank vegetation and verge vegetation. **Bank vegetation** refers to trees, shrubs, grasses, and other vegetation actually growing on the stream bank (sides of the stream channel). The trees from this area overhanging the stream form the stream **canopy**. Bank vegetation provides food and shelter for aquatic organisms in the form of fallen twigs, leaves, fruits, flowers, and branches.



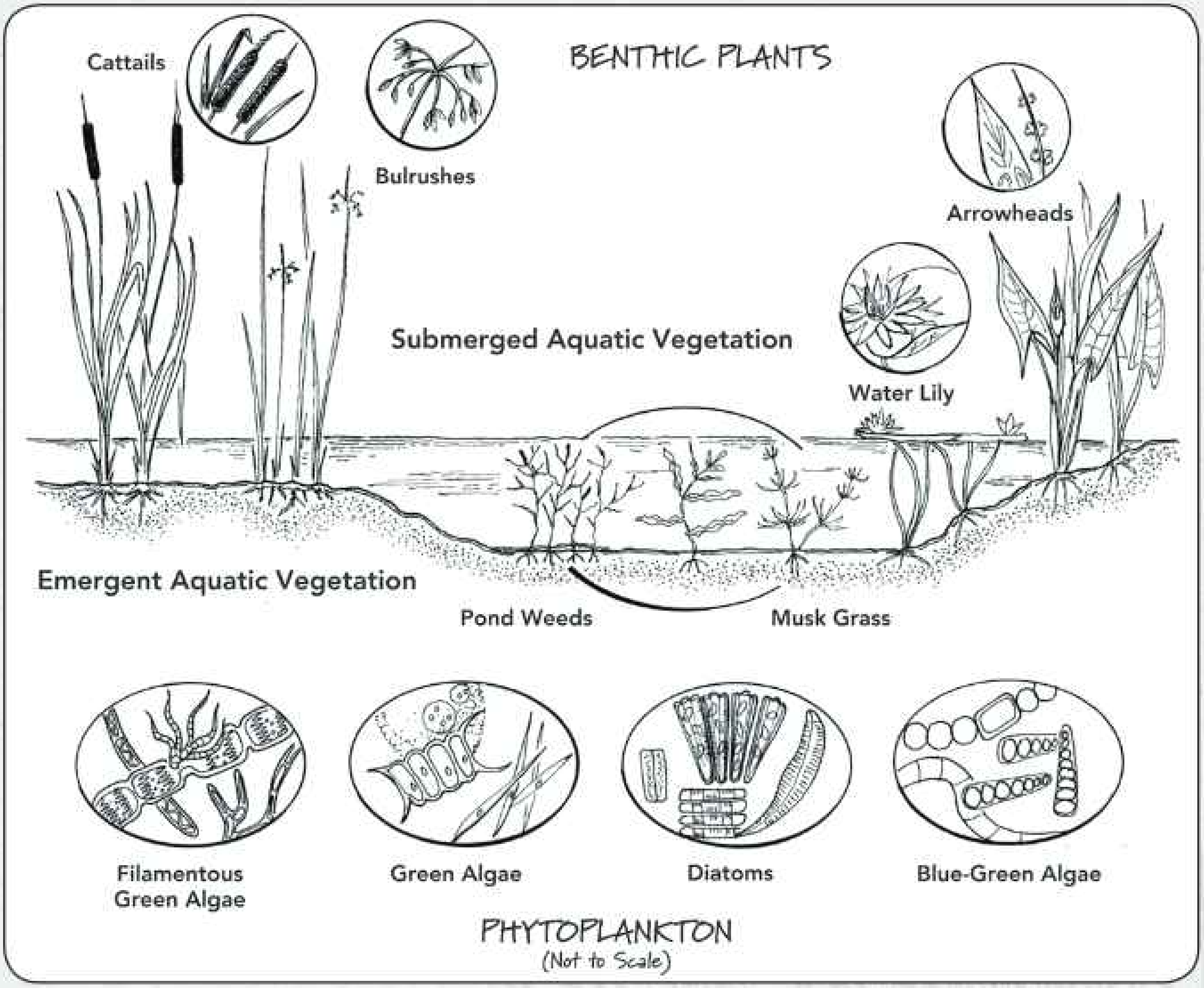
Verge vegetation starts at the top of the bank and extends to the next major line of vegetation or to the point of a change in land use. Excellent verge vegetation is a wide corridor of undisturbed vegetation. In areas of very poor verge vegetation, patchy growth, or bare soil erosion increases.

The vegetation in the riparian area affects many features of the waterway ecology such as light, temperature, and bank stability. It acts as a physical buffer to reduce runoff and is especially effective as a sediment trap. Vegetation forms habitats for birds and small mammals; provides overhanging shelter for fish; serves as a place for emergent insects to rest, feed, and lay eggs; improves water quality by filtering runoff before it reaches the water; and promotes sediment deposition on the land, instead of in the water. It slows floodwaters and reduces the total volume of water entering the stream through root absorption. It provides opportunities for recreational activities, such as fishing, hiking, bird watching, picnicking, and camping. Riparian vegetation is vulnerable to destruction by natural change and careless human management. It is as important to protect as the river channel itself.

Aquatic Vegetation

There are two basic categories of **aquatic plant life**:

1. **Benthic plants** are aquatic plants that grow attached to or rooted in the bottom of the body of water. They withdraw nutrients from the sediment at the bottom of the water. There are two types of benthic plants: a) submerged aquatic vegetation (SAV), plants that grow totally underwater, and b) emergent aquatic vegetation (EAV), plants whose lower parts are in water, but whose upper parts stick out above the surface of the water.
2. **Phytoplankton** are numerous species of algae existing as single cells or small groups of cells that float freely in water and use the nutrients dissolved in the water.



Resources

Sediment and Erosion

SEDIMENT

Sediments are small particles of both organic and inorganic materials. Individual sediment particles have a large surface area and can act as chemical "magnets," allowing other molecules to stick to them. These molecules may be nutrients, oils, pesticides, metal ions, or other potentially toxic materials. Areas in which a great deal of sediment has been deposited may have high accumulated concentrations of long lasting toxic chemicals such as pesticide residues and heavy metal ions. Suspended sediments contribute to the turbidity (cloudiness) of water, decreasing the light available for plant growth. As sediments settle to the bottom, they can fill in the waterway and even smother the benthos (bottom-dwelling plants and animals) living there. Sediments can also contribute to **eutrophication** because of the nutrients that may cling to them.

Sediment load is divided into three categories. **Suspended sediment load** contains organic and inorganic particles suspended in and carried by moving water. **Dissolved sediment load** is dissolved organic and inorganic material carried in moving water. **Bed sediment load** is coarse material, such as gravel, stones, and boulders carried along the bottom of the channel by moving water.

EROSION

Erosion is the process by which soil particles are picked up and carried away by water or wind. In most terrestrial (land) ecosystems, a cover of vegetation protects the soil from erosion. The force of wind is blocked by vegetation, and the force of heavy rain is broken against the plants so that water filters gently into the loose soil. As the water moves through the vegetative cover, it doesn't have enough energy to pick up soil particles. Since most of the water soaks in, there isn't much runoff. However, when soil is bare and unprotected, wind and the force of falling rain breaks up the clumpy structure of the soil, and smaller particles may be carried away in runoff. This is erosion. Loose particles may wash into spaces between other particles of soil, clogging the spaces and decreasing the soil's ability to absorb water. This results in more water running off the surface, causing further erosion.

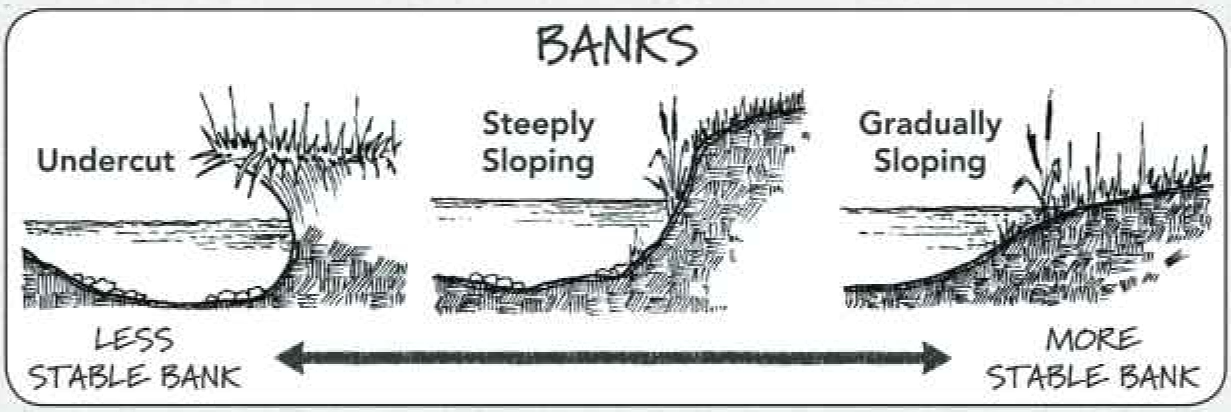
As more runoff occurs, water runs into streams that have more water moving faster so that more particles of soil wash downstream. The lighter particles of humus and clay are the first to go, leaving coarser soil made of sand, stone and rock. Clay and humus hold most of the nutrients and water in soil. As they are removed, most of the nutrients are removed with them, and the bodies of water that receive these materials may get an oversupply of nutrients. Additionally, the water-holding capacity of the soil is reduced. The subsequent runoff increases stream sediments that degrade the water supply, increase turbidity, adversely affect aquatic organisms, and transport chemical pollutants.

Resources

Banks

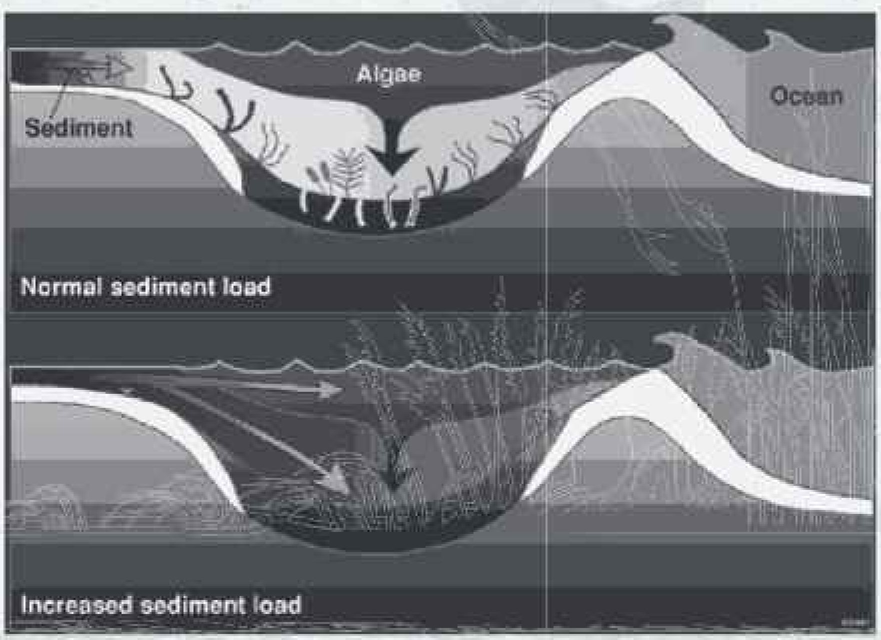
When a bank is bare, it is more prone to erosion because the soil is not held fast by vegetation. When looking at a stream habitat, the **percent of bank bare soil** gives a numerical indication of the lack of vegetation and allows us to quantify its vulnerability to erosion.

Bank slumping and movement is an indication of the degree of erosion that has already occurred. A stable bank has gentle slopes, even vegetation, and no evidence of undercutting of the banks by the stream. A severely eroded or unstable bank has extensive cracking and many areas that have already collapsed.



Climate and Land Use Effects of Sedimentation

Climatic changes in heavier rainfall may result in increased erosion and sedimentation, which refers to the natural process of sediments settling and being deposited. Heavier rainfalls can affect the stability of the stream slope, while also altering stream flows that transport sediments more rapidly. mean there are more extreme storms, higher stream levels, and an alterations in stream flow. While climate is a significant driver in increased in erosion, sediment transportation, and bank failures, various other factors can also be at play here. Specifically, alterations in land use and land cover that come from human development and forest management. This can substantially impact the probability of bank slumping and movement through increased sedimentation and erosion.



Resources

Sediment in the Chesapeake Bay from the Chesapeake Bay Program

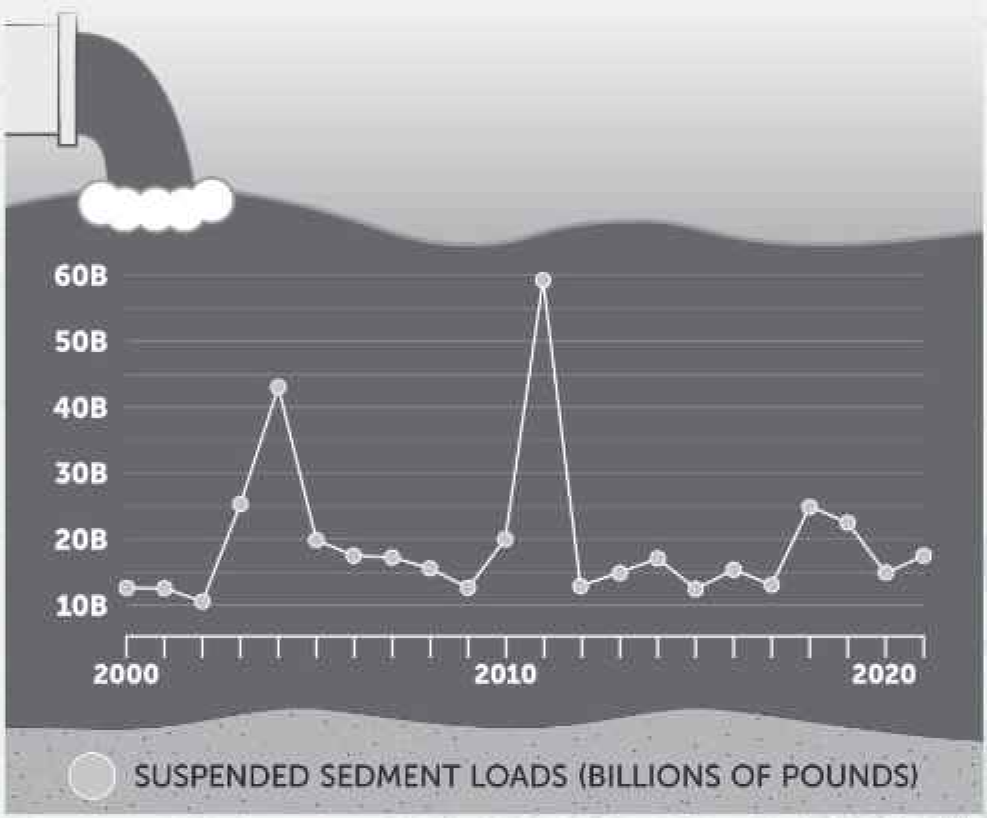
Eroding land and stream banks are called watershed sources of sediment. Watershed erosion increases when land is cleared of vegetation to make way for agriculture and development. Scientists estimate that most of the sediment that flows into the Chesapeake Bay comes from watershed sources.

In the Bay watershed, river basins with the highest percentage of agricultural lands yield the highest amount of sediment each year. Basins with the highest percentage of forest cover, on the other hand, yield the lowest amount of sediment. On a per-acre basis, construction sites can produce the most sediment of all land uses—as much as 10 to 20 times that of agricultural lands.

Since the seventeenth century, watershed-wide changes in land use and land cover have disrupted the natural processes of erosion:

- During the eighteenth and nineteenth centuries, 70 to 80 percent of the watershed's forest cover was removed to supply people with firewood and farmland. Cleared, exposed land is prone to erosion.
- Deforestation peaked in the late nineteenth century, and while reforestation did take place during the twentieth century, increased urbanization has continued to contribute to high erosion rates.
- Studies of sediment cores in the Bay and its tributaries show a four- to five-fold increase in sediment accumulation rates in some parts of the Bay since the 1800s.

Accelerated sea-level rise caused by climate change can also increase tidal erosion.



Resources

Environmental Justice

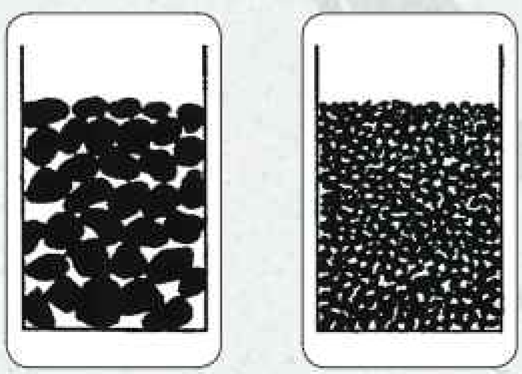
The influences of warming temperatures have stronger impacts on vulnerable populations of minorities, people 25 and older with no high school diploma, elderly people, and low-income communities, who have had higher energy bills through the increasing use of air conditioning. These concerns are part of environmental justice, the the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income.

Conserving land is more than planting trees, maintaining the shorelines, and creating buffers. It is essential to also consider the history and culture of the land. The Rappahannock Tribe lost their land as they were forced out by English settlers. Only a small section of their land was left for them, but in 2022, a deal with the Chesapeake Conservancy helped return the land to the tribe after 350 years. This land, known as Fones Cliffs, was also renamed to its original name of Pissacoack. The Anacostia River in Washington D.C has been known as the "forgotten river" in the area, as it has faced many years of degredation and pollution. The area, predominantly black, raises concerns on social justice and water quality. In 2023, the Potomac Electric Power Company was held accountable for their contamination of the river and agreed to pay $57 million in its restoration. This is just one area of the Potomac River watershed in which land conservation is tied t o a history and culture of marginalized communities.

PoreSpace and Permeability

Soil is composed of tiny pieces of broken rock and organic matter, with space between the particles being filled by water or air. The amount of space depends on the shape and size of the particles and how tightly the particles are packed. **Pore space** is the amount of space (or pores) between soil particles. Porosity determines the amount of air and water that a given amount of sediment, soil, or rock can hold.

Greater pore space
Higher permeability
Coarse grain



Less pore space
Lower permeability
Fine grain

CROSS SECTION OF TWO DIFFERENT SOIL SAMPLES

Permeability is the ease with which water can flow through the spaces between soil particles. It is determined by properties of the soil, such as porosity and how the soil particles clump together. If the particles are lined up in rows so that straight channels are made, the water can flow through quickly. If the water has to wind around the particles, it flows more slowly so the soil is less permeable. Both pore size and continuity (whether the pores are connected to make "tunnels") influence permeability.

Soil Permeability Testing

Your group will determine soil permeability. Permeability is directly affected by the degree of **soil compaction**. Compaction occurs when soil is squeezed over and over, such as when it is walked on repeatedly. As air spaces between soil particles get smaller, the particles pack more tightly and stick together. Soil that is too compacted will not hold water. Plant roots cannot penetrate the soil to grow properly. The other extreme is just as bad. If soil is too loose, spaces between the particles are so large that water drains out quickly and completely, before plant roots can soak it up. The activity below is one way to test soil permeability.

MATERIALS LIST FOR EACH GROUP:

- 14 oz steel can with both ends removed (or you may substitute a section of PVC pipe, 6-inch length x 3 inches in diameter)
- Water
- Graduated cylinder
- Watch with a second hand

PROCEDURE:

Resources

Note any evidence of human activities that would affect soil compaction (e.g. well-worn foot path, horse trail). Make sure these are included on your sketch of the study site.

1. **Push and twist the steel can, or the PVC pipe, about 1 inch into the ground.**

2. **Measure 100 mL of water. Quickly pour the water into the can, making sure that all the water is inside the can. Time how long it takes for the water to drain out of the can. Record the time in seconds on your Data Sheet. After two minutes, if the water has not drained, stop the test and record the result as "greater than 120 seconds."**

3. **Remove the can. Replace the dirt from the hole, returning the area to the way it was before you began the investigation.**

Turbidity

Turbidity is a measure of water clarity. The greater the turbidity, the cloudier the water. Turbidity is caused by solids suspended in water that reduce the passage of light through the water. Suspended materials can include many substances such as soil particles (clay, silt, and sand), algae or other forms of plankton, and bacteria. Soil particles range in size from less than 0.004 mm (clay) to 0.004 to 0.063 mm (silt) to 0.063 to 2.0 mm (sand). High turbidity can damage fish and other organisms, interfere with their ability to find food, and block light to plants. In this activity, you will measure turbidity using a test kit that compares the turbidity of a water sample with distilled water. Your results will be measured in Jackson Turbidity Units (JTUs).

MATERIALS LIST FOR EACH GROUP:

- 1 bottle Standard Turbidity Reagent
- 1 plastic pipette (0.5 mL) with cap
- 2 turbidity columns (marked "Std" and "Sample")
- 1 stirring rod
- Distilled water

PROCEDURE:

1. **Choose a sampling site away from the shore and below the surface of the water.**
2. **Fill the "Sample" turbidity column to the 50 mL line with a sample of this water. If the black dot on the bottom of the tube is not visible when you look down through the water column, pour out half the sample so that the tube is filled to just the 25 mL line.**
3. **Fill the "Std" turbidity column with an equal amount of distilled water; this is the standard.**
4. **Look down through the water in each tube to the black dot at the bottom. If the dot is equally clear in both tubes, turbidity is zero. If the dot in the "Sample" column is less clear than in the "Std " column, continue to Step 5.**
5. **Vigorously shake the closed bottle of Standard Turbidity Reagent.**
6. **Fill the pipette (eyedropper) to the 0.5 mL line with Turbidity Reagent and add entire 0.5 mL to "Std" column.**
7. **Gently stir the "Std" column to mix the Turbidity Reagent in with the distilled water.**
8. **Look down into each tube to the black dot. If the "Std" column dot and the "Sample" column dot are equally cloudy, note the total amount (in mL) of Turbidity Reagent added. Use the table below to determine the JTUs. If the "Sample" column dot is still cloudier than the "Std" column dot, continue to Step 9. Remember, you are matching the cloudiness of the water in the two columns, not color. Ignore color differences between the two columns of water.**
9. **Add Turbidity Reagent in 0.5 mL increments to the standard ("Std") water tube. Gently stir the column after each addition. Check turbidity by viewing the black dots in each tube. Continue to add Turbidity Reagent until the clarity of the black dot appears equal in both tubes. Record the amount of Turbidity Reagent added.**
10. **Use the following table to determine the turbidity in JTUs.**

TURBIDITY TEST RESULTS

No. of Measured Additions	Amount mL	50 mL Gradation JTU	Secchi Disk Comparison cm	25 mL Gradation JTU	Secchi Disk Comparison cm
1	0.5	5	120	10	90
2	1.0	10	90	20	30
3	1.5	15	60	30	25
4	2.0	20	30	40	20
5	2.5	25	28	50	15
6	3.0	30	25	60	13
7	3.5	35	23	70	10
8	4.0	40	20	80	7.5
9	4.5	45	18	90	5
10	5.0	50	15	100	2.5
15	7.5	75	9	150	0
20	10.0	100	2.5	200	0

Apparent Color and Odor

APPARENT COLOR

The apparent color of water is the result of both dissolved substances and suspended materials and can provide useful information about the water's source and content. A white surface under pure water appears blue, because blue light and blue-green light are the wavelengths best transmitted through water. Natural metallic ions, plankton, algae, industrial pollution, and plant pigments from humus and peat may all produce colors in water.

Determine the apparent color of water by lowering a white disk far enough below the water surface to produce a distinct color. Use the table of colors below to hypothesize the source of the water color.

Color	Source
Blue	Low accumulation of dissolved materials and particulate matter (indicating low productivity)
Yellow or brown	Organic materials: humus, peat, decaying plants
Reddish or deep yellow	Algae
Green	Phytoplankton or algae
Yellow, red, brown, or gray	Soil runoff

Resources

ODOR

The odor (smell or scent) of water can indicate what's in it. Odor can be caused by the natural presence of algae and dissolved minerals. Odor can also be caused by municipal or industrial wastes, decomposing plants, or microbial activity. Odor affects how acceptable we find drinking water, how willing we are to use a waterway for recreational purposes, and how fish and other aquatic foods taste to us.

Odor Test: Your nose is an excellent odor-detecting device. Collect a water sample in a wide-mouthed jar. Waft the air above the water sample toward you with your hand. Use the table of odors below to describe what you smell.

Odor	Nature of Odor
Aromatic (spicy)	Cloves, lavender, lemon
Flowery	Geranium, violet, vanilla
Chemical	Industrial wastes, chlorine, oil refinery wastes, medicinal, sulfur (rotten eggs)
Disagreeable/unpleasant	Fishy, pigpen, septic (stale sewage)
Earthy	Damp earth
Grassy	Crushed grass
Musty	Decomposing straw, mold

Stream Speed

The physical characteristics, or abiotic factors, of a stream are most important in determining which organisms live there. Stream speed is one of the most important characteristics of any stream. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity and lower overall productivity than slow-moving streams. A slow-moving stream is warmer, has less light penetration, a higher nutrient concentration, and more organism diversity. Speed will vary in different portions of the stream moving faster over riffles and the outer edges of a bend and slower through pools and the inner edges of a bend. During the following investigation, you will determine the overall speed of the stream.

MATERIALS LIST FOR EACH GROUP:

- Orange, rubber ducky or ping pong ball
- Watch with a second hand
- Flash tape
- 10-meter length of rope

PROCEDURE:

1. **Measure a 10-meter section of stream. String flashing tape across the stream at each end of the 10-meter segment.**

2. **Drop the orange into the middle of the stream above the beginning of your 10-meter segment.**

3. **Start timing when the orange crosses the "start" line of your 10-meter segment.**

4. **Record the time in seconds that it takes the orange to travel the length of your stream segment.**

5. **Repeat Step 2 for a total of 3 trials. Average your results.**

6. **Divide 10 meters by your average time to get the midstream speed in meters/sec. Overall stream speed is approximately 0.8 of the midstream speed. (Water in the middle of the stream channel moves more quickly than water on the sides and bottom.) Use the following formula to calculate overall stream speed.**

   Overall stream speed (meters/sec) = midstream speed (meters/sec) X 0.8

7. **Record the overall stream speed on your data sheet.**

Low Impact Development Strategies

According to the Environmental Protection Agency, Low Impact Development (LID) is "a sustainable landscaping approach that can be used to replicate or restore natural watershed functions and/or address targeted watershed goals and objectives." Another way to think about it is as a way to keep water where it falls, rather than having it flood the storm drains and then our creeks and rivers. Runoff changes the quality of water in the creeks. It also erodes the streambanks, filling the streams with sediment and making it uninhabitable for fish and other living organisms in the creek.

The purpose of all the LID strategies listed below is to slow the flow of stormwater, and to allow it to percolate (or drip) through soil. As it filters through soil (think about water dripping through a coffee filter), it is stripped of harmful chemicals. It eventually returns to the groundwater, considerably cleaner than when it started. Just as important, by keeping rainwater where it falls, it reduces the harmful effects of rainwater rushing through stormdrains and eroding streambanks. LID strategies are cost effective because they reduce the amount of water going to water treatment plants. The techniques described below can be used individually, but are most effective when multiples ones are implemented in a single area. Nonpoint source pollution is caused by many small, cumulative actions; it can be remedied in the same way.

GREEN ROOFS

According to the American Institute of Architects (AIA), a green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproof membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Rooftop ponds are another form of green roofs used to treat residential greywater (water used for laundry, dishwashing and bathing) which can be filtered and used for landscaping.

There are two types of green roofs: intensive roofs, which are thicker and can support a wider variety of plants but are heavier and require more maintenance, and extensive roofs, which are covered in a light layer of vegetation and are lighter than an intensive green roof.

To see a green roof in action, visit the new Washington Nationals Park. It is the nation's first major professional stadium to become Leadership in Energy and Environmental Design (LEED) Silver Certified by the U.S. Green Building Council. The Washington Nationals' ballpark features a 6,300 square foot green roof over the concession area.

RAIN GARDENS

Living in the Potomac watershed, you've probably seen creeks that look like canyons (similar to the picture on the left), with tree roots barely hanging onto soil. This is the result of water running off streets and into storm drains. Rather than soaking into the ground, which is what water would do if there weren't so many paved (or impermeable) surfaces like roofs, it is all funneled through storm drains to creeks in our neighborhoods.

Resources

All gardens need rain, but there is a kind of garden that is constructed to capture and hold stormwater so that it filters through the soil rather than becoming runoff that overwhelms our creeks and rivers. Rain gardens not only beautify an area, they bring larger benefits to the environment, both locally and beyond.

A rain garden takes advantage of rainfall and stormwater runoff in its design and plant selection. Usually, it is a small garden designed to withstand the extremes of moisture and concentrations of nutrients, particularly nitrogen and phosphorus, found in stormwater runoff. It must also be able to survive periods of extreme drought as well. Rain gardens ideally are sited close to the source of the runoff and serve to slow the stormwater as it travels downhill, giving the stormwater more time to infiltrate (or drip through the soil) and less opportunity to gain momentum and erosive power.

A rain garden is unique in how it gets its water and what happens to that water once it pools in the garden. Below the surface of the garden, a number of processes are occurring which imitate the hydrologic (or water) action of a healthy forest. Soils are prepared and plants selected for the rain garden. The garden collects stormwater, and cleans it as it slowly drains down into the soil. Rain gardens are designed to drain within four hours after a 1" rainstorm, so plants need to be able to tolerate lots of water at one time followed by dry periods. Nitrogen and phosphorus levels and overall sediment in the stormwater are reduced by the action of the plants on the water.   Multiple rain gardens in a single watershed will have a positive collective effect on both the volume and quality of stormwater runoff.

Resources

RAIN BARRELS

Rain barrels are above ground water storage containers which, when positioned under a downspout, capture rain runoff from the roof of a building.

Instead of letting the water flow down a driveway or a sidewalk and into a storm drain, it is collected. A rainfall event of less than half an inch can easily fill up a 50-gallon rain barrel. A rain barrel at each downspout can quickly start to collect enough water to keep flowerbeds, gardens, or houseplants well watered.

With the cost of water increasing and drought restrictions forcing many communities to reduce the amount of water they use on their yards, rain barrels have become more popular.

People have been saving rain water to use during dry periods for centuries. Today, rain barrels save money by reducing the amount of water purchased from the utility company. If you collect water from your roof to use in the garden, you don't get charged for it coming in or going out!

AMENDED SOIL

Soil on well-worn trails is usually compacted so tightly by hikers that it's more like a street surface. The soil no longer has space between the individual particles so it can't absorb rainwater. To make the soil more absorbent, decaying leaf mold, compost, and grass clippings are added to increase the spaces between soil particles. The amended soil can hold more moisture, which in turn reduces runoff and its damaging effects on local streams. Soil amendments help increase the infiltration capacity of the soil, filter potential pollutants, reduce the need for chemical fertilizers and pesticides, and hold more rainwater.

This garden, in the Potomac River watershed, was designed with low impact considerations. The river of stone allows water to percolate through the soil. The plantings, including Indian grass, lowbush blueberries and blue flag iris, are all native to our watershed. The terracing reduces sedimentation.

UNDERGROUND STORAGE

On-site, underground stormwater retention / detention captures and stores (or holds) stormwater collected from surrounding impervious areas. Stored water is then released directly through an outlet pipe back into natural waters at rates designed to reduce peak flows and mimic pre-development conditions. In some cases stored water can be allowed to infiltrate to recharge groundwater.

USING NATIVE PLANTS AND TREES

Our native soils were built by deep-rooted vegetation, such as trees and native grasses that could withstand drought and fire, and by vast, productive wetlands. Stormwater entered the streams primarily through the soils, not over land. More lawn, roads, and roofs prevent water from percolating, or filtering, through the soil and shift the burden of water to our storm drains and, eventually, our streams and rivers. If we convert even a fraction of our lawns back to deep-rooted vegetation we can rebuild the sod and reduce runoff.

FILTER STRIPS

Filter strips are land areas of planted or indigenous vegetation between a potential, pollutant-source area and a surface-water body, such as a stream. A filter strip, like the one pictured, provides water-quality protection by reducing the amount of sediment, organic matter, and some nutrients and pesticides in the runoff at the edge of the field. This diverts the pollution from the stream-water. Filter strips also provide erosion protection since the vegetation covers an area of soil that otherwise might be likely to erode quickly.

Some cities are experimenting with filter strips along streets.

SWALES

Swales are shallow, low depressions in the ground designed to gather rain during storms and hold it for a few hours or days to let it infiltrate into the soil. Swales ideally are tree-lined and store water for the immediate landscape as well as help cleanse the water.

BERMS

Berms are raised beds that can be used to direct water to swales or rain gardens.

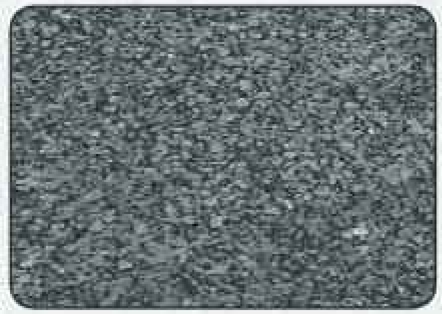
PERMEABLE PAVEMENT

Permeable pavement, unlike asphalt or concrete surfaces, allows stormwater to drain into soil rather than become runoff. There are a number of different kinds of permeable pavement, with varying uses.

Some examples include the following:

Permeable Interlocking Concrete Pavers

Concrete Grid Pavers "Turfstone"



Porous Concrete

Low Impact Development Ideas:

Want to learn more? There are many online resources with descriptions of Low Impact Development. A search of "low impact development methods" will provide you with plenty of ideas.

Student Pages

Bay in a Beaker Procedure and Tables

1. Label the beakers 1, 2, 3, 4, 5 and date each one.
2. Fill beakers 1, 2, 3, and 4 with 750 mL of water from a stream, pond, river, or bay.
3. Fill beaker 5 with 750 mL of distilled water.
4. Weigh 10 mg of fertilizer. Add this to beaker 1.
5. Weigh 25 mg of fertilizer. Add this to beaker 2.
6. Weigh 10 mg of fertilizer. Add this to beaker 3.
7. Cover beaker 3 completely with a paper bag so that no light can enter the beaker.
8. Do not add any fertilizer to the water in beaker 4.
9. Weigh 25 mg of fertilizer and add this to the distilled water in beaker 5.
10. Place all the beakers in a sunny windowsill or under a bright light. Do not seal the beakers. You will examine and record observations on days 1, 5, and 10.
11. What is the purpose of the bag covering beaker 3?
12. What is the purpose of beaker 4?
13. What is the purpose of beaker 5?

Beaker 1
750 mL stream H_2O
10 mg fertilizer

Beaker 2
750 mL stream H_2O
25 mg fertilizer

Beaker 3
750 mL stream H_2O
10 mg fertilizer
(Cover with paper bag)

Beaker 4
750 mL stream H_2O
(Control – No fertilizer)

Beaker 5
750 mL Distilled H_2O
10mg fertilizer

Bay in a Beaker Procedure and Tables

14. Write a prediction to describe what you think will happen in each beaker.

TABLE I: PREDICTED CHANGES IN EACH BEAKER

Beaker	Actual Changes
1	
2	
3	
4	
5	

15. Record your observations in Table II.

TABLE II: OBSERVATIONS

Beaker	Day 1	Day 5	Day 10
1	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
2	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
3	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
4	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:
5	Color:	Color:	Color:
	Clarity:	Clarity:	Clarity:
	Odor:	Odor:	Odor:

Bay in a Beaker Procedure and Tables

16. **After 10 days, use your observations in Table II to help you:**
    1) Summarize the changes you observed in each beaker.
    2) Determine whether your observations support the predictions you made in Table I.
    3) Record your responses in Table III.

TABLE III

Beaker	Summary of Changes	Prediction Supported?
1		
2		
3		
4		
5		

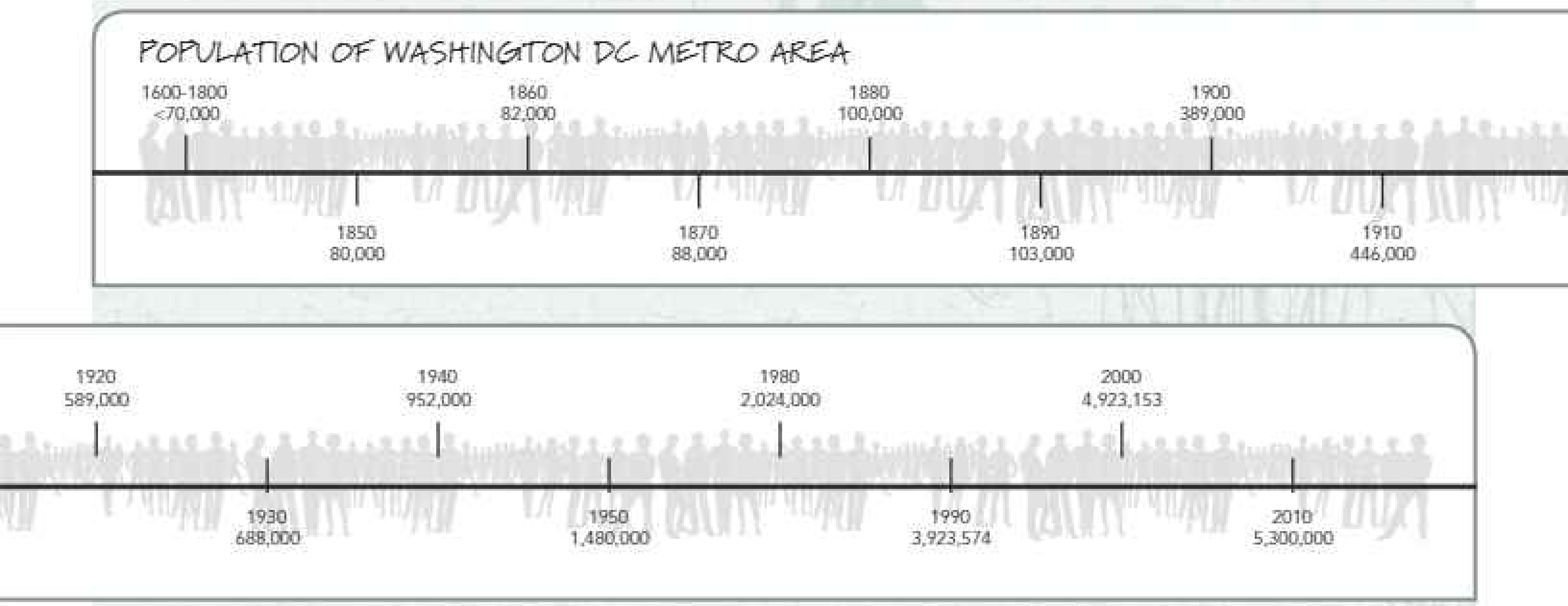
17. **Explain the process of eutrophication. (Refer to the article on "Effects of Pollutants on the River" on page 37 of the Resources Section.)**

18. **Which beaker(s) represent cultural eutrophication that is the result of runoff from farms and fertilized lawns? Explain.**

19. **Did your observations support your prediction? Explain.**

Potomac River Watershed Timeline Procedure

1. How old is your school?
2. How old is the building in which you live?
3. How old is the local shopping mall?
4. Imagine your community 50 years ago. Make a list of things you could find today that were there 50 years ago.
5. Draw a vertical line across one end of the paper strip. Label this line "1600."
6. One centimeter represents 5 years, and 2 centimeters represent a decade or 10 years.
7. Using this scale, start at the 1600 line and draw a line for each decade from 1600 to the present.
8. Read carefully the "Potomac River Watershed" distributed by your teacher.
9. Using a different color for each issue, draw a horizontal line on your 1-meter paper strip, beginning when each of these problems was first noted and continuing up to a date when the problem was solved:
    - Brown: sedimentation (soil erosion)
    - Blue: sewage (bacterial contamination)
    - Green: cultural eutrophication (excess nutrients such as nitrogen or phosphorus)
    - Red: chemical pollution (such as acids from mining, or urban and industrial runoff)
    - Purple: trash and litter pollution
10. On each colored line, draw an "X" at the year in which an attempt to address this problem was made. Using the same color, circle the date in the "History" that represents this "X."
11. Which of these problems have been solved? Choose one of the problems to research and find out how severe this problem is today in the Potomac River. Try using current newspaper or magazine articles, or searching on the Internet.



Color Me a Watershed Procedure and Tables

1. **What factors can affect runoff in a watershed?**

____

____

2. **Think about what happens when rain falls on land with different types of ground cover. Rank the following from 1 (having the greatest runoff) to 4 (having the least runoff).**
   - ___ a grassy meadow
   - ___ a well-worn dirt path
   - ___ a concrete parking lot
   - ___ a corn field

3. **Locate the map grids A & B. These maps represent an imaginary watershed and show changes in land use over 100 years. Each individual block is marked with a letter to indicate ground cover or land use (i.e., R= river, F= forest, A= agriculture, H= housing, W= wetland, G = grassy meadow). Color the blocks on both maps by using the following color code.**

Color Key	
River	Blue
Forest	Green
Agriculture	Orange
Housing	Red
Wetlands	Yellow
Grassy Meadow	Brown

4. **Assume each square on the map represents one square kilometer. How much total area is represented on each map?**

____

____

5. **Determine how many square kilometers (km2) each type of ground cover/land use occupies on the map. Record the results in Table IV Ground Cover/Land Use. Calculate and record the percentage (%) that each type of ground cover occupies. Repeat these steps for Map B.**

F	R	R	F	F	R	F	F	F	F	F	F	F	F	F
F	R	R	F	F	R	F	F	F	F	F	F	F	F	F
F	R	R	F	F	R	F	F	F	F	F	F	F	F	R
F	R	R	R	F	R	F	F	F	F	F	F	F	F	R
F	F	R	R	F	R	F	F	F	R	G	G	R	R	F
F	F	R	R	R	R	F	F	F	R	G	G	R	R	F
F	F	F	R	R	R	F	F	F	R	G	G	R	F	F
F	F	F	R	R	R	R	F	F	R	W	R	R	F	F
R	R	F	F	R	R	R	F	F	R	W	R	R	F	F
F	R	R	F	R	R	R	W	W	R	W	R	F	F	F
F	F	R	R	W	R	R	R	W	W	R	R	F	F	F
F	F	R	R	W	R	R	R	W	W	R	W	F	F	F
F	F	F	R	R	W	R	R	R	W	R	W	F	F	F
F	F	F	F	R	R	W	R	R	R	R	W	F	F	F
F	F	F	F	F	R	R	R	R	R	A	A	F	F	F
F	F	F	F	F	F	R	R	R	R	A	A	F	F	F
F	F	F	F	F	F	H	R	R	R	R	A	F	F	F
F	F	F	F	F	F	H	H	R	R	R	A	F	F	F
F	F	F	F	F	F	H	H	H	R	R	R	A	F	F
F	F	F	F	F	F	H	H	H	H	R	R	A	F	F
F	F	F	F	F	F	F	G	G	H	H	R	R	F	F
F	F	F	F	F	F	F	G	G	G	H	R	R	R	F
F	F	F	F	F	F	F	G	G	G	G	A	R	R	R
F	F	F	F	F	F	F	G	G	G	G	G	A	R	R

100 YEARS AGO

F	R	R	A	F	R	F	F	F	F	F	F	F	F	F
F	R	R	A	F	R	F	F	F	F	H	H	F	F	F
F	R	R	A	F	R	F	F	F	F	H	H	F	F	R
F	R	R	R	F	R	F	F	F	F	H	H	F	F	R
A	A	R	R	F	R	F	F	F	R	G	G	R	R	F
A	A	R	R	R	R	F	F	F	R	H	H	R	R	F
A	A	A	R	R	R	F	F	A	R	H	H	R	F	F
A	A	A	R	R	R	R	F	A	R	H	R	R	F	F
R	R	A	F	R	R	R	F	A	R	H	R	R	F	F
H	R	R	F	R	R	R	W	A	R	H	R	A	A	F
H	H	R	R	W	R	R	R	A	A	R	R	A	A	F
H	H	R	R	W	R	R	R	A	A	R	A	A	A	F
A	A	A	R	R	W	R	R	R	A	R	A	A	A	F
A	A	A	A	R	R	W	R	R	R	R	A	A	A	F
F	F	A	A	A	R	R	R	R	R	A	A	A	A	F
F	F	H	H	H	H	R	R	R	R	A	A	A	A	F
F	F	H	H	H	H	H	R	R	R	R	H	H	H	F
F	F	F	F	F	H	H	H	R	R	R	H	H	H	F
F	F	F	F	F	H	H	H	H	R	R	R	H	H	F
F	F	F	F	F	H	H	H	H	H	R	R	H	H	F
F	F	F	F	F	F	G	H	H	H	H	R	R	H	F
F	A	A	F	F	F	G	H	H	H	H	R	R	R	F
F	A	A	F	F	F	G	A	A	A	A	A	R	R	R
F	F	F	F	F	F	G	A	A	A	A	A	A	R	R

PRESENT

Color Me a Watershed Procedure and Tables

TABLE IV: GROUND COVER/LAND USE

	Map A: 100 Years Ago		Map B: Present		
Ground Cover	Area (km^2)	% of Total	Area (km^2)	% of Total	Change in % of Total
River					
Forest					
Agriculture					
Housing					
Wetland					
Grassy Meadow					

6. Compute change in % of total in Table IV Ground Cover/Land Use. Be certain to include a "+" to show an increase or " – " to indicate a decrease.

7. Refer to Table IV and your colored maps to answer questions a and b.
   a. Which categories of ground cover/land use showed the greatest percent increase?
   b. Describe where these changes in ground cover/land use occurred in relation to the river.

8. If all rain is absorbed when it hits the ground, there is no runoff. If no rain is absorbed because it is blocked by impervious surfaces such as asphalt roads, all the rain becomes runoff. These are two extremes to emphasize how runoff is created. Answer the following question after reading the section on erosion on page 39 of the Resources. Do you think a watershed is healthier if rain is absorbed into earth or runs off into the nearest waterway? Explain.

---

9. Find out if the volume of runoff changed in this imaginary watershed over the 100-year period. Assume that during one rainfall 12,500,000 m 3 of rain fell evenly over the entire watershed on map A, and the same amount of rain fell evenly on the watershed on map B. To find out how the total runoff changed because of the changes in land use, follow these steps.
   a. How much rain fell on each block?
   b. Multiply the km2 of each ground cover/land use (from Table IV) by the amount of rain that fell on each block. This will tell how much rain fell on each category of ground cover. Record these totals in Table V.

TABLE V: VOLUME OF RAIN (M^3)

Ground Cover/Land Use	Map A: 100 Years Ago	Map B: Present
Forest		
Agriculture		
Housing		
Wetland		
Grassy meadow		

   c. Table V shows how much rain runs off each category of ground cover/land use. Complete both columns in the table by multiplying the volumes you recorded in Table V by the percent runoff listed in Table VI for each category. Then total each column.

Color Me a Watershed Procedure and Tables

TABLE VI: VOLUME OF RUNOFF (M^3)

Ground Cover and Land Use	Percent Runoff	Map A: 100 Years Ago	Map B: Present
Forest			
Agriculture			
Housing			
Wetlands			
Grassy meadow			
	Total runoff		
	Difference in runoff		

d. Compute the change in total runoff from the watershed over 100 years. Be certain to include a "+" to show an increase or "–" to indicate a decrease.

10. In previous activities, you have seen that land use affects runoff, and runoff affects water quality. Describe how the water quality has probably changed.

Datasheet for Data Analysis

Bridging the Watershed

Don't Get Sedimental Datasheet

Date: ____

Teacher: ____

Park: ____ Study Site: ____

Park Rangers & Educators: (one per row)	Group Members: (one per row)

Latitude: North _____° _____' _____" Longitude: West _____° _____' _____"

Why is it important to know the latitude and longitude?

	Yesterday	Today
Air Temperature	_____ °C	_____ °C
Cloud Cover	☐ Clear ☐ Partly Cloudy ☐ Cloudy	☐ Clear ☐ Partly Cloudy ☐ Cloudy
Precipitation	☐ None ☐ Rain ☐ Other	☐ None ☐ Rain ☐ Other

How could weather affect today's field study?

Water Color ____ Water Odor ____ Water Temperature _____ °C

Stream Speed:

Trial 1 ____ Seconds

Trial 2 ____ Seconds

Trial 3 ____ Seconds

Average ____ Seconds (Add all 3 Trials and divide by 3)

Stream Speed measured with digital probe: ____ ft/s

Use the average time from above in the calculation below to determine average stream speed

10m / ____ [average time]= ____ meters/second

Because we test speed only at the surface of the stream, we use a 'fudge factor' of 0.8 to adjust for an overall stream speed. Use the average speed from above to find the overall stream speed:

Average Speed x 0.8 (fudge factor) = ____ meters/second

Sketch the study site, showing all details that affect your field study:

Soil Permeability: Seconds Turbidity: JTU's

Characteristics for Stream Habitat Assessment

	Excellent Score: 4	Good Score: 3	Fair Score: 2	Poor Score: 1	Site Score
Verge Vegetation	vegetation present, canopy intact	vegetation and canopy nearly intact	vegetation disturbed	cleared land or urban development	
Bank Vegetation	vegetaton in undisturbed state	vegetation slightly disturbed	vegetation moderately disturbed	vegetation severely disturbed	
% Bare Soil on Bank	0 - 10%	11 - 40%	41 - 80%	81 - 100%	
Bank Erosion	stable, no sign of erosion	very occasional local erosion	some erosion evident	severe bank failure; extensive cracking and fall-ins	
Bank Slumping and Movement	no movement	slight movement on bank	moderate bank collapses	severe bank failure; extensive cracking and fall-ins	
Bends and Riffles	Bends present; 5 - 10 riffles in 10 m; some snags	Bends present; 1 - 4 riffles in 10 m	occasional bend; 1 -2 riffles in 50m; few snags	straight channel; riffles/pools absent; no snags	
Turbidity (JTUs)	0 - 10	11 - 40	41 - 150	> 150	
Aquatic Vegetation	little vegetation - uncluttered look; fairly small numbers of many different kinds of plants	moderate amounts of vegetation	cluttered, weedy conditions; vegetation sometimes luxurious and green; seasonal algal blooms	choked, weedy conditions; heavy algal blooms or no vegetation at all	
Sediment Deposition	less than 20% of stream bottom affected by extensive sediment deposition; minor accumulation of fine and coarse material at snags; little or no enlargement of islands or point bars	20 - 50% of stream bottom affected by extensive sediment deposition; moderate accumulation; substantial sediment movement during major storms; some new increase in bar formation	50 - 80% of stream bottom affected by extensive sediment deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movements during storm events	> 80% of stream bottom affected by extensive sediment deposition; heavy deposits; mud, silt and/or sand in pools; pools almost absent due to deposition	
				Total Score	

Stream Habitat Rating		
32-36	Excellent	natural or virtually natural state
23-31	Good	some alteration from natural state
14-22	Fair	significant alteration from natural state
0-13	Poor	very degraded habitat

Habitat Rating:

Class Data Analysis Procedure and Tables

1. **Compare your data with the data from the other group(s).**
   In the park, each group gathered data about the stream habitat and recorded it on the data sheet on in the Student Pages. Record group data on Table VII: Class Data for Color, Odor, Soil Permeability, and Stream Speed and Table VIII: Class Data for Stream Habitat Assessment to determine the class average or consensus for each of the stream characteristics.

2. **Rate the stream habitat.**

3. **Each group will use the class data to prepare a report. Begin your report with the name of the park you visited, the date of your visit, and the name of the module. Define the study area and weather conditions using data from the first page of your group's data sheet.**

4. **In addition to using the rating chart, be sure to examine and include the other factors that indicate stream health such as apparent color, odor, soil permeability and stream speed from table VII.**

TABLE VII: CLASS DATA FOR COLOR, ODOR, SOIL PERMEABILITY, AND STREAM SPEED

Characteristic	Group 1	Group 2	Group 3	Group 4	Group 5	Class Average
Apparent Odor						
Odor						
Soil Permeability (Seconds)						
Stream Speed (m/sec)						

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TABLE VIII: CLASS DATA FOR STREAM HABITAT ASSESSMENT

Characteristic	Group 1	Group 2	Group 3	Group 4	Group 5	Class Average
Verge Vegetation						
Bank Vegetation						
% Bare Soil On Bank						
Bank Erosion						
Bank Slumping and Movement						
Bends and Riffles						
Turbidity (JTUs)						
Aquatic Vegetation						
Sediment Deposition						
					Class Total Score	

Lower levels of sedimentation

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Higher levels of sedimentation

Stream Habitat Rating
36 - 32 = Excellent
31 - 23 = Good
22 - 14 = Fair
13 - 0 = Poor

Note: The lower the stream habitat rating, the higher the level of sedimentation.

5. **The Performance List follows. Use this list to evaluate your group's final report, as well as your group's data collection efforts in the park.**

Group Members ______________________________________ Date ________________

Performance Criteria	Assessment		
	Points	Group	Teacher
1 All group data are entered, and the stream habitat is rated accurately.			
2 All class data are entered, and the stream habitat is rated accurately by average or consensus.			
3 The report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data, a descriptive assessment of the health of the stream is included.			
5 Individual stream characteristics that were significant are noted and possible reasons for them are proposed.			
6 The summary is clear and concise, and accurately reflects the findings of the study.			
7 Scientific terminology and concepts are accurately explained and applied to illustrate major points of the report.			
8 Visual aids (photographs, charts, graphs, and drawings, etc.) enhance understanding of the text.			
9 Visuals are clearly titled, labeled, and referenced within the text.			
10 Language used in the report is purposeful, descriptive, and appropriate for the intended audience.			
Total			

Teacher Comments: