Alice Ferguson Foundation's

BRIDGING THE WATERSHED

WATERSHED WATCHDOGS

Assessing Water Quality

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

WATERSHED WATCHDOGS

Assessing Water Quality

Teacher's Guide & Resources

Alice Ferguson Foundation, 2001 Bryan Point Road, Accokeek, Maryland 20607
Phone: 301-292-5665 • Email: btwinquiries@fergusonfoundation.org • www.fergusonfoundation.org

Design & Artistic Production by: Media Graphics, Inc. • 7141 Rice Street • Falls Church, VA 22042 • www.designwithmgi.com

TABLE OF CONTENTS

MODULE ORGANIZER

This module is divided into three sections: activities completed prior to the park visit (Pre-Field Study), activities conducted in the park (Field Study), and the activities completed subsequent to the park visit (Post-Field Study). In the Pre-Field Study activities, students learn about their watershed and water quality testing procedures in order to be prepared to take full advantage of the experience in the park. Once in the park, students will have an opportunity to use the water-testing skills they learned to collect water quality data from a river or stream. In the context of collecting authentic data in the park, students gain a deeper understanding of the connection between the choices they make and the water quality in their watershed. When students return to the classroom, they will reflect on their visit to the park and compile a group report that will summarize the data collected. Students will also engage in an interactive activity to understand the causes for pollution of the Potomac River and they will design and conduct experiments intended to clean up polluted water.

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	
Close to Home: Your Local Watershed	• To identify your local watersheds. • To understand the impact of surrounding land on the health of a stream or the national park study site.	• Internet access
Who Polluted the Potomac?	• To become aware of the many different ways pollutants can enter a river. • To realize that protecting the environment is not a one-time action, but that it requires ongoing changes in our daily habits.	• 1 gallon tap water in a clear container • 16 labeled film canisters or other small container • Dry clay soil • Crumbled dry leaves • Vegetable oil • Assorted litter (pull tabs, Styrofoam, etc.) • Nylon fishing line • Potassium chloride or ¼ tsp. baking powder • Molasses, coffee or food color mix • Yellow food color mixed in water • Toilet paper • Vinegar • Monosodium phosphate or baking soda • Blue/green food color mixed in water • Soapy water • Red food color mixed in water
Understanding the Water Quality Index	• To gain confidence and competence in water quality testing protocol. • To determine the Water Quality Index (WQI) for two unknown water samples. • To understand the importance of each parameter used to determine the WQI.	• Water quality testing kits for each parameter • 2 unknown water samples from different sources (from each source you will have a fresh sample and a 5-day old sample for the 5-day BOD) • 2 fecal coliform plates (prepared for the students 24-48 hours in advance of the classroom activity)

TITLE	GOAL(S)	MATERIALS LIST
FIELD STUDY		
What's the Health of this Stream?	To determine water quality of a stream in a local national park.	• Appropriate clothing • Adequate food and drink • All other materials will be provided
POST-FIELD STUDY		
Data Analysis	• To complete fecal coliform and Biochemical Oxygen Demand (BOD) tests in order to calculate the group's WQI. • To compute the average WQI for the stream using all class data, not just your group's data.	• Computer with Internet access
Who Polluted the Potomac: Can We Clean It?	To design and conduct a procedure to clean a polluted water sample.	• 200 mL of polluted water from "Who Polluted the Potomac?" • Density separation troughs • Funnels • Rubbber tubing with pinch clamps • Filter paper • Sand • Straws • Pea gravel • Activated charcoal (available in aquarium supply stores) • Paper cups • Food coloring • Beakers • Graduated cylinders • Gauze or cheesecloth • Sponges • Filter Floss • Cardboard • Baking soda • Ferric chloride • Aluminum sulfate (alum) • Stirring rods
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 for further reading.		

Close to Home: Your Local Watershed

ENGAGEMENT

BACKGROUND INFORMATION:

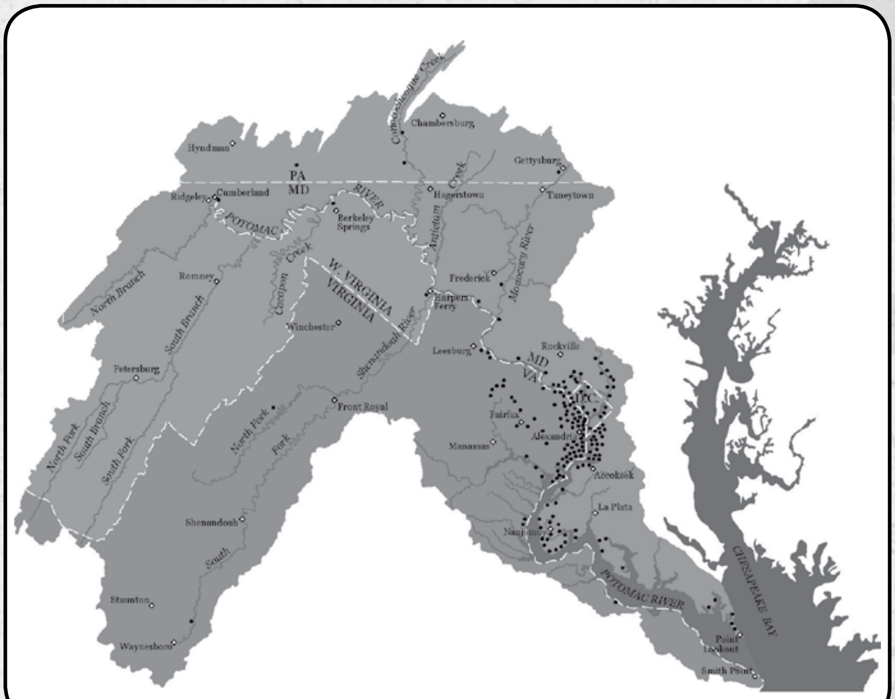
Freshwater resources are essential to humans, animals, and plants. The metropolitan Washington, D.C. area draws most of the water for human use from the Potomac River. At the same time, the Potomac is also used to carry away wastewater. The Potomac River is part of the Potomac River watershed, which in turn is part of the larger Chesapeake Bay watershed. The Environmental Protection Agency (EPA) maintains a listing of watersheds in the United States, water quality monitoring data from the watershed, and citizen-based groups at work in the watersheds.

In this activity, students will use the EPA website to identify and investigate the health of the watersheds in which they live and attend school.

PROCEDURE:

1. Log onto the EPA web site at http://cfpub.epa.gov/surf/locate/index.cfm.

2. Scroll down to "Locate by geographic unit." Select "zip code (5 digit number)," type in your local postal Zip Code and click "submit." Record in Table I: Local Watershed Information the 8-digit United States Geological Survey (USGS) Cataloging Code.



Goal:

To identify and investigate the health of your local watersheds.

Class Time:

45 minutes

Group Size:

Students can work individually or in groups of 2-3.

Materials List for Every 2 Students:

Internet access

Special Considerations:

If access to the Internet is not readily available, the information can be printed out in advance from the website to be used in class to complete the activity.

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

Close to Home: Your Local Watershed

ENGAGEMENT

TABLE 1: LOCAL WATERSHED INFORMATION (WASHINGTON, D.C. METRO AREA)

	Name of Watershed	USGS Cataloging Code
Home	The most likely answers for zip codes in the Washington, D.C. metropolitan area are: • Middle Potomac-Anacostia-Occoquan • Lower Potomac • Patuxent • Middle Potomac-Catoctin	8 – digit codes vary with watershed names. The most likely answers for zip codes in the Washington, D.C. metropolitan area are: 02070010 02070011 02060006 02070008
School		

CLOSE TO HOME EXTENSION: FIELDSCOPE

Goal:

To complete the classroom activity by applying the concepts learned using FieldScope, an online Geographic Information System (GIS) developed by National Geographic, to learn more about the impact of land use (residential, agricultural and industrial) on the health of the local stream or national park field study site.

Class Time:

90 minutes

Group Size:

Groups of 2

Once students are familiar with how to manipulate the tools on Fieldscope, have them use it to address the following scenario:

The entire Mid-Atlantic region has just experienced extremely heavy rainfall associated with a tropical storm. Most areas received six to seven inches of rain in a 24-hour period. As a field scientist, you know that much of the stormwater runoff has gone into your local stream. You must create a list of what kinds of pollutants and sedimentary material you expect to see in your local stream after this storm event by examining land use around your local stream. Rank the list from greatest to least amount of material you would expect to find.

Students can further explore the EPA website to supplement their knowledge of their local stream or the stream in the chosen national park field study site.

1. **Scroll down to "Citizen-based Groups at work in this watershed," and click the link. Have students choose five groups and fill out the information for each in table 2.**

Table 2: Citizen-Based Groups at Work in This Watershed

Group Name	Area Of Monitoring	# Of Volunteers	Website?
Alliance for the Chesapeake Bay	Pennsylvania, Maryland, Virginia	125	Yes

2. **Scroll down to "Assessments of Watershed Health," and click on the link "Impaired Water for this Watershed." Choose a state (D.C., MD, or VA) and click the link. When the new page loads, scroll down and locate the chart titled "Causes of Impairment for Reporting Year 2010: Virginia, Middle Potomac-Anacostia-Occoquan." Choose five water bodies and list the cause of impairment for each in table 3.**

Table 3: Causes of Impairment of Watershed

Name Of Watershed	State Report	Water Body Name	Cause Of Impairment
Middle Potomac-Anacostia-Occoquan	VA	Accotink Creek	Benthic macroinvertebrate bioassessments

3. **Students can further explore the cause of impairment by clicking on the box titled, "Frequent Questions," on the right-hand side of the screen. Scroll down to and click on "Assessing Water Quality (Questions and Answers)."**

Who Polluted the Potomac?

ELABORATION

BACKGROUND INFORMATION:

You will read aloud an interactive story dramatizing how population growth and changes in land use can cause a river to become so polluted that it is transformed from a valuable resource into a repugnant and even toxic wastewater. The emphasis in this activity is on nonpoint source pollution, which originates from sources that are not easy to identify. Nonpoint source pollution is mostly the result of runoff and includes fertilizers and other toxic chemicals washing off lawns and farmland; oil, grease, and litter from streets and parking lots; soil eroding off construction sites; and air pollutants washed to earth by rain. These pollutants are very difficult to measure and control, and they have a great impact on life in a water body.

This exercise demonstrates that we are all part of the problem. It also shows that protecting the environment is not a one-time event, but requires ongoing changes in our daily habits. After completing this activity, students should be ready to discuss the actions they can take to help prevent pollution.

Fill the 16 canisters as indicated in the following chart:

“Factor”	Substance in Canister
Construction site	3mL dry clay soil
Trees	Dry leaves, crumbled
Motorboat	1mL vegetable oil
Beach party	Assorted litter (pull tabs, Styrofoam, etc.)
Family picnic	Assorted litter (paper, plastic wrap)
People fishing	Tangle of nylon fishing line
Farmer	Potassium chloride or 2mL baking powder
Barnyard	Molasses, coffee, or food color mix
Homeowner	Yellow food color, water, toilet paper
Coal mine	1/4 canister vinegar
Electric power plant	1/4 canister vinegar

(Chart continued on next page.)

Goal:

- To become aware of the many different ways pollutants can enter a river.
- To realize that protecting the environment is not a one-time action, but that it requires ongoing changes in our daily habits.

Materials List:

- Water quality testing kits for each parameter
- 1 gallon of tap water in a clear, colorless, wide-mouthed container
- 16 labels (found on page 6)
- 16 film canisters or other small containers (one for each factor)

Suggested Adaptation

- Teachers with water-quality testing kits and labs can test the water before and after the story for apparent color, odor, pH, orthophosphates, nitrates and turbidity using the techniques from “Understanding the Water Quality Index” exploration activity.

Who Polluted the Potomac?

ELABORATION

PROCEDURE:

1. Before class begins, make a copy of the following labels. Cut them out and tape them to film canisters. Fill the canisters with the ingredients listed on pages 3-4. Put one gallon of tap water into the container to represent the Potomac River.

"Factor"	Substance in Canister
Commuters	¼ canister of vinegar
Gardeners	2mL monosodium phosphate or baking soda
Antifreeze	Blue/green food color and water
Washing the car	½ canister of soapy water
Mysterious liquid	1mL diluted red food color and water

Note: The canisters need to be labeled and filled before the class begins.

2. Have students arrange themselves around the container of water that represents the "Potomac River."

3. Distribute a set of canisters to the students representing the factors that impact a waterway. Students should keep the identity of the factor/contents of their canister a secret. Explain that when a factor is mentioned as you read the story (below), the student with the corresponding canister should empty the contents into the "river" (the jar of water).

4. Read the following story out loud to the class.

THE STORY OF "WHO POLLUTED THE POTOMAC?"

For many thousands of years, people have lived on the banks of the Potomac River. They hunted in the great forests, harvested food from the wetlands, and fished the river.

Imagine that the jar of water was taken from this river about 500 years ago.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

In 1608, Captain John Smith explored the Potomac for settlement by European colonists. He kept a journal of his discoveries, writing about the Native American villages, the forests, and the river itself. He described tributaries of "sweet waters" and the river so full of fish that he and his crew tried to scoop them up with a frying pan.

Soon colonists began to arrive. They found fertile land for farming, forests teeming with game, and a river that provided ample food and water. It was an outstanding environment for settlement, and the colonists prospered.

Who Polluted the Potomac?

ELABORATION

CANNISTER LABELS

The Potomac River has changed a lot in the past 400 years. This is the story of the changes.

Listen for the name of the character printed on your canister. When you hear your character named, open the canister and dump its contents into the river.

Imagine now that everything in the story is happening in the present – maybe even while we're sitting here today.

Who Polluted the Potomac?

ELABORATION

A sudden downpour drenches the area. The pounding rain is washing loose soil from a nearby **CONSTRUCTION SITE** into the river. High winds whip through the **TREES** and blow leaves into the water.

Imagine that the jar of water was taken from this just after a downpour.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

In a short while, the storm passes over and the sun comes out again. People head for the river to have fun. Some zoom up and down the river in **MOTORBOATS** and don't notice that a little engine oil leaks into the water.

A group of friends have spread blankets on the shore for a **BEACH PARTY**. Lots of families are **PICNICKING** in the parks, too. Some of these people have left trash on the shore. At the next high tide, or during the next rain, that trash will wash into the river. On the dock, a **PERSON FISHING** snags the hook on a log and breaks the nylon fishing line.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Not everyone is out playing today. A **FARMER** has been fertilizing cornfields close to the shore. The rain washed some of the fertilizer off the land and into the nearby river. The farmer also keeps pigs and other animals in the **BARNYARD**. As the rainwater drains out of the barnyard, it carries some of the manure into a little creek behind the farm. The creek flows into the river.

Out in the country, high on a hill overlooking the river, is an old house. It is not connected to the city sewer system. Wastewater from the house goes into a septic tank underground. The **HOMEOWNER** has not maintained the septic tank, and poorly treated sewage is seeping into the river.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Who Polluted the Potomac?

ELABORATION

Upstream is a **COAL MINE**. Rainwater drained down into the shaft and soaked the piles of wastes and scraps from mining. This made the water become acidic - like strong vinegar. Then the acid water trickled back out into the river.

The **ELECTRIC POWER PLANT** on the river burns coal to produce electricity. The gases coming out of the smokestacks combine with moisture in the air to form acids. The pollution falls back to Earth as acid rain or snow.

Many **COMMUTERS** drive their cars to and from work. Car exhaust fumes (just like the power plant fumes) cause more acid rain. If a car is not kept in good repair, it might also leak oil or other fluids, which will be washed off the pavement and into the river with the next rain.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Let's look in on some typical activities around the neighborhood. Lots of **GARDENERS** are out working in their yards today. Many of them are using weed killers and insect sprays to keep their lawns pretty. The next rainfall will wash these poisons into a little creek nearby, and then into the river.

There's a father teaching his daughter how to change the antifreeze in her truck. They pour out the used **ANTIFREEZE** on the driveway. Antifreeze is sweet-tasting and can poison an animal that licks it. It can also get into the nearby creek and poison fish.

Later, father and daughter **WASH THE CAR**. The soapy water rushes down the driveway into the storm drain; the storm drain empties into the river. Phosphates in detergents used to be a pollution problem because they acted like fertilizer, making too much algae grow in the river. Laws were passed to stop the use of phosphate soaps in order to help solve the algae problems. But the grease and grime on a car contain asphalt from the roads, asbestos from the brakes, rubber particles from the tires, heavy metals, and rust. If the man and his daughter had gone to the local car wash, the water would have been treated before it was returned to the river.

Next door a family is cleaning out their garage. They find an old rusty can with a tattered skull and crossbones label still stuck on it. What could it be? It looks dangerous, and they want to get rid of it before someone gets hurt. But how? One of the kids gets the idea: "Let's pour it down the drain out by the curb. Hurry up! " So the **MYSTERIOUS LIQUID** goes down the storm drain. The poison is out of sight, but it is headed for the river.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Who Polluted the Potomac?

ELABORATION

Think about what was in the canisters:

1. **Could something be done to prevent that type of pollution from entering the river?**

2. **What could you start doing right away to help improve the health of the watershed where you live?**

3. **What do you think would have to be done to this water to make it safe to drink?**

4. **Once pollutants have entered the river, how can we get them out?**

5. **How can we clean up the river?**

6. **Do you think it is easier to prevent pollution or clean it up?**

TIGHTLY CLOSE THE CONTAINER OF POLLUTED WATER AND SAVE IT. Students will be using it after their field study to create strategies for cleaning their river. (See "Polluted Water Can We Clean It" on page 25.)

Note: Extensions to this activity provide options for isolating the nonpoint source pollution in various tributaries of the Potomac River and exploring differences in the subwatersheds' size, land use, and development patterns. Extensions are provided with your supplementary materials.

Understanding Water Quality Index

EXPLORATION

BACKGROUND INFORMATION:

This is a collaborative laboratory activity in which students will be part of a team that will test two unknown water samples for the nine parameters listed in Table II: Water Quality Parameters used to determine the WQI. Students will learn how to conduct and interpret water quality tests and the WQI. The WQI is a standard index created by the National Sanitation Foundation to determine and compare the health of rivers.

Each student will use the resource information to become the "resident expert" for at least one parameter. The "expert" will report to the team on the name of the parameter, its importance, acceptable water quality levels, and the units used to measure the parameter. The "expert" will conduct the test on both water samples and will share test results with team members to determine the WQI for each sample.

TABLE II: WATER QUALITY PARAMETERS

Parameter	Description
Dissolved Oxygen	% saturation of gaseous oxygen dissolved in water
Fecal Coliform*	Bacteria from feces of humans and other vertebrate animals
pH	Acidity or alkalinity
Biochemical Oxygen Demand (BOD)*	Quantity of oxygen used by bacteria to decompose organic matter
Temperature Change	Difference in temperature in two different locations of a stream
Orthophosphates	Phosphate (phosphorus and oxygen), (PO_4^{-3}) ion unbonded
Nitrates	Nitrate (nitrogen and oxygen), (NO_3^{-1}) ion
Turbidity	Relative clarity of water
Total Dissolved Solids	Dissolved particles

*These test samples require advance/special preparation prior to the students' analysis at school. See "Special Considerations"on page 11.

BOD SAMPLE (PREPARE FIVE DAYS IN ADVANCE OF CLASSROOM USE)

1. **Rinse the water sampling bottle with the test site water.**

2. **Empty the bottle and recap it.**

Goal:

- To gain **confidence** and competence in water quality testing protocol.
- To determine the Water Quality Index (WQI) for two unknown water samples.
- To understand the importance of each parameter used to determine the WQI.

Class Time:

90 minutes

Group Size:

Groups of 4 students. Students should work in the same groups during the field study. In the interests of time and efficiency, the nine tests should be divided into the following four subsets, with one student completing each subset.

- Dissolved Oxygen and Biochemical Oxygen Demand
- Turbidity and Total Dissolved Solids
- Nitrates and pH
- Orthophosphates and Fecal Coliform
- Teacher will supply the value for change of water temperature

If time permits, encourage students to practice all 9 tests.

Materials List for Each Group:

- Water quality testing kits for each parameter
- 2 unknown water samples from different sources (from each source you will have a fresh sample and a 5-day old sample for the 5-day BOD)

3. Hold the bottle under water and remove the cap. Be sure to hold onto the cap.

4. Allow the water to gently fill the bottle. Ensure there are no air bubbles in the bottle.

5. Keep the bottle underwater. Tap the bottle to release any air bubbles.

6. With the bottle still underwater, recap the bottle.

7. Take the bottle out of the water. Make sure no air bubbles are inside. If there are air bubbles, repeat the sample collection to get a sample with no bubbles.

8. Keep the bottle in the dark at 20°C for five days.

9. Also, 5 days in advance of classroom use, you will need to measure the DO for each of the sources at the time of collection of the BOD samples. The students will use this data to compute the change in DO over the 5 days, (i.e., the BOD).

FECAL COLIFORM (PREPARE 24-48 HOURS IN ADVANCE OF CLASSROOM USE)

1. Keep Coliscan medium chilled until you mix it with the water sample. (Coliscan Easygel Kit is available from Micrology Laboratories at www.micrologylabs.com.)

2. Use a sterile calibrated dropper to add 3 mL of sample water to the Coliscan medium bottle.

3. Tightly cap the Coliscan + water mixture and shake gently.

4. Pour the Coliscan + water mixture into the pre-treated Petri dish. Carefully swirl the mixture to cover the bottom of the Petri dish.

5. Set the Petri dish on a level surface until the liquid forms a gel, about ½ hour.

6. Tape the Petri dish shut with clear tape.

7. Place the Petri dish in a warm place (29.5-35.0^{o} C). Incubate for 24-48 hours.

8. Count fecal coliform colonies according to instructions that come with the Coliscan kit.

- 2 fecal coliform plates (prepared for the students 24 -48 hours in advance of the classroom activity)

Special Considerations:

Students' understanding of the test procedures will prepare them to conduct the same tests on the field study.

While students will not bring the data sheets to the park, you may want to familiarize them with it in the classroom so they are well-prepared when they arrive at the field study. All student pages are included in the supplementary materials and can be printed out as needed.

Understanding Water Quality Index

EXPLORATION

Temperature Change: In the classroom, students won't have the opportunity to determine temperature change. Choose two values for all groups to use. In general, the cleaner (purer) the sample, the smaller the temperature change (e.g., 0˚ C for distilled water and 3-6˚ C for polluted water).

Phosphates: Total phosphates are typically used to compute WQI. Orthophosphate testing, rather than total phosphate, has been chosen to reduce testing time and the need for a heat source. Providing a heat source in the park is not practical.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **Your group will determine the WQI for two unknown water samples by conducting a test for each of the nine parameters. Each member of the team will become the "resident expert" for one or more of the parameters listed in Table II: Water Quality Parameters on page 10. You will perform these same nine tests to determine the WQI of a stream when you visit a national park. In the interest of time and efficiency, the nine tests should be divided into four subsets, with one group member completing each subset.**
   - Dissolved Oxygen and Biochemical Oxygen Demand (your teacher will supply water temperature for this test)
   - Turbidity and Total Dissolved Solids
   - Nitrates and pH
   - Orthophosphates and Fecal Coliform
   - Temperature change (your teacher will supply the values for this parameter)

2. **Decide who will research each set of parameters. Research your parameters by reading the resource information provided by your teacher. Prepare a report to present to your team after research is completed. Your report should include answers to the following:**

   a. What parameters are you researching?

   b. What is the importance of each parameter?

   c. What are the acceptable levels?

   d. What units are used to measure the parameter?

Understanding Water Quality Index

EXPLORATION

WATERSHED WATCHDOGS PARAMETERS FOR DETERMINING WQI

Parameter	Importance	Acceptable Levels	Units of Measure
Dissolved Oxygen	Aquatic animals and plants must have dissolved oxygen in order to live	80-125% or > 5mg/L	% saturation and mg/L
Fecal Coliform	Humans can become sick from fecal coliform	0 for drinking water, < 235 for swimming	colonies/100 mL
pH	pH outside of the acceptable range reduces the ability of organisms to survive, thereby reducing biodiversity	6.5 to 8.5	Numbers compared on a scale
BOD	Lower amounts of available oxygen limit aquatic life to organisms highly tolerant of low oxygen levels	8 to 150	mg/L
Temperature Change	Large temperature change can "shock" organisms	< 5	° Celsius
Orthophosphates	Excess phosphates cause algae bloom	< 4	mg/L
Nitrates	Excess nitrates can be caused by over-fertilization or manure contamination	< 4.4	mg/L
Turbidity	High turbidity can reduce light to aquatic plants and clog gills	< 0.5 for drinking water < 40 for aquatic life	Jackson Turbidity Units (JTU)
Total Dissolved Solids	Contain substances needed by aquatic plants and animals	100 to 2,000	ppm

3. **Gather materials and test your two water samples. (Note: Your teacher will provide your team with two 5-day old water samples to test BOD, two prepared fecal coliform plates, and two temperature change values to use in determining the WQI.)**

4. **Record test results in Table III: Water Quality Index for Unknown Samples on page 14.**

5. **Determine the Q-value for your test results by using the Weighting Graphs beginning on page 43 of the Teacher Resources. Record your values on Table III.**

6. **On Table III, multiply your Q-value by the Weighting Factor. Record the product in the TOTAL block. (Note: The weighting factor indicates the importance of each parameter to the WQI. You will note on Table III that parameters have been ordered according to their weighting factor.)**

7. **Share your parameter report and your test results with team members. As other team members report, record their test results on Table III.**

8. **Calculate the Water Quality Index for each sample by adding the values in the TOTAL column.**

9. **Use the Water Quality Index Interpretation Scale on page 14 to describe the water quality of each sample. Record the descriptions in Table III.**

Understanding Water Quality Index

EXPLORATION

10. **The resident expert will share with other group member's information about the acceptable levels for and importance of his or her parameter. In Table IV on page 15, place a check in the appropriate box indicating whether the level of each parameter is acceptable or unacceptable.**

WATER QUALITY INDEX INTERPRETATION

WQI	Description
100 - 90	Excellent
89 - 70	Good
69 - 50	Moderate
49 - 25	Bad
24 - 0	Very Bad

TABLE III: WATER QUALITY INDEX FOR UNKNOWN SAMPLES

	Unknown Sample 1 (Distilled Water)				Unknown Sample 2 (Pond, Stream, or Aquarium Water)			
Parameter	**Test Result**	**Q-Value**	**Weighting Factor**	**TOTAL**	**Test Result**	**Q-Value**	**Weighting Factor**	**TOTAL**
Dissolved Oxygen __________ mg/L Water Temp: __________˚ C	50% sat.	45	0.17	7.65	90% sat.	95	0.17	16.15
Fecal Coliform	0 colonies/ 100mL	96	0.16	15.40	200 colonies /100mL	35	0.16	5.60
pH	7	90	0.11	9.90	6	54	0.11	5.94
BOD __________ mg/L of 5-day sample	0 mg/L	98	0.11	10.80	10 mg/L	11	0.11	3.74
Temperature Change Water Temp: ____˚ C ____˚ C	△0˚ C	92	0.10	9.20	△5˚ C	73	0.10	7.30
Orthophosphates	0 mg/L	100	0.10	10.00	5 mg/L	12	0.10	1.20
Nitrates	0 mg/L	97	0.10	9.70	30 mg/L	27	0.10	2.70
Turbidity	0 JTU	96	0.08	7.68	40 JTU	45	0.08	3.60
Total Dissolved Solids	0 mg/L	80	0.07	5.60	250 mg/L	66	0.07	4.62
	Overall WQI			**85.90**	**Overall WQI**			**50.90**
	WQI Description			**Good**	**WQI Description**			**Moderate**

Note: To calculate BOD, subtract DO in mg/L of the 5-day old sample from the DO in mg/L on the day the sample is taken.

Understanding Water Quality Index

EXPLORATION

TABLE IV: EVALUATION OF TESTS RESULTS

	Sample 1		Sample 2	
Parameter	Within Acceptable Levels	Outside Acceptable Levels	Within Acceptable Levels	Outside Acceptable Levels
Dissolved Oxygen		√	√	
Fecal Coliform	√			√
pH	√		√	
BOD	√			√
Temperature Change	√		√	
Orthophosphates	√			√
Nitrates	√			√
Turbidity	√			√
Total Dissolved Solids		√	√	

11. Choose two parameters whose values fall outside acceptable levels. Assume that the samples came from a freshwater stream. Suggest possible reasons for the unacceptable levels.

Answers will vary.

Understanding Water Quality Index

EXPLORATION

Computing Water Quality Index with Missing Parameters

Sometimes it is not practical or possible to collect or read a sample for the Fecal Coliform or Biochemical Oxygen Demand tests. In these cases, WQI-results are skewed because the "Total" does not account for missing data. It is possible to adjust this score so that students can make an educated guess at what the WQI description should have been. Each parameter result has a maximum potential contribution to the overall stream score, and so one can adjust the total based on that potential.

Fecal Coliform accounts for 16% of the total result.
Biochemical Oxygen Demand accounts for 11% of the total result.

If you are computing the WQI without a Fecal Coliform result, follow this:

Divide your raw "Total" by 84 to get your adjusted "Total."

If you are computing the WQI without a Biochemical Oxygen Demand result, follow this:

Divide your raw "Total" by 89 to get your adjusted "Total."

If you are computing the WQI without a Fecal Coliform result OR Biochemical Oxygen Demand results, follow this:

Divide your raw "Total" by 73 to get your adjusted "Total."

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

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. Also, review the directions for data collection in this module. Students can read the resource information that provides the information they will use in the park.

The AFF educator will have all the supplies for the field study activities.

PARK INFORMATION:

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

Before the site visit, review the resource information with your students. Also, review the directions for the data collection and completion of Table VIII: Characteristics for Stream Habitat Assessment in the student pages.

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.

Goal:

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

Plan Wisely for Your Students' Field Study

ENGAGEMENT

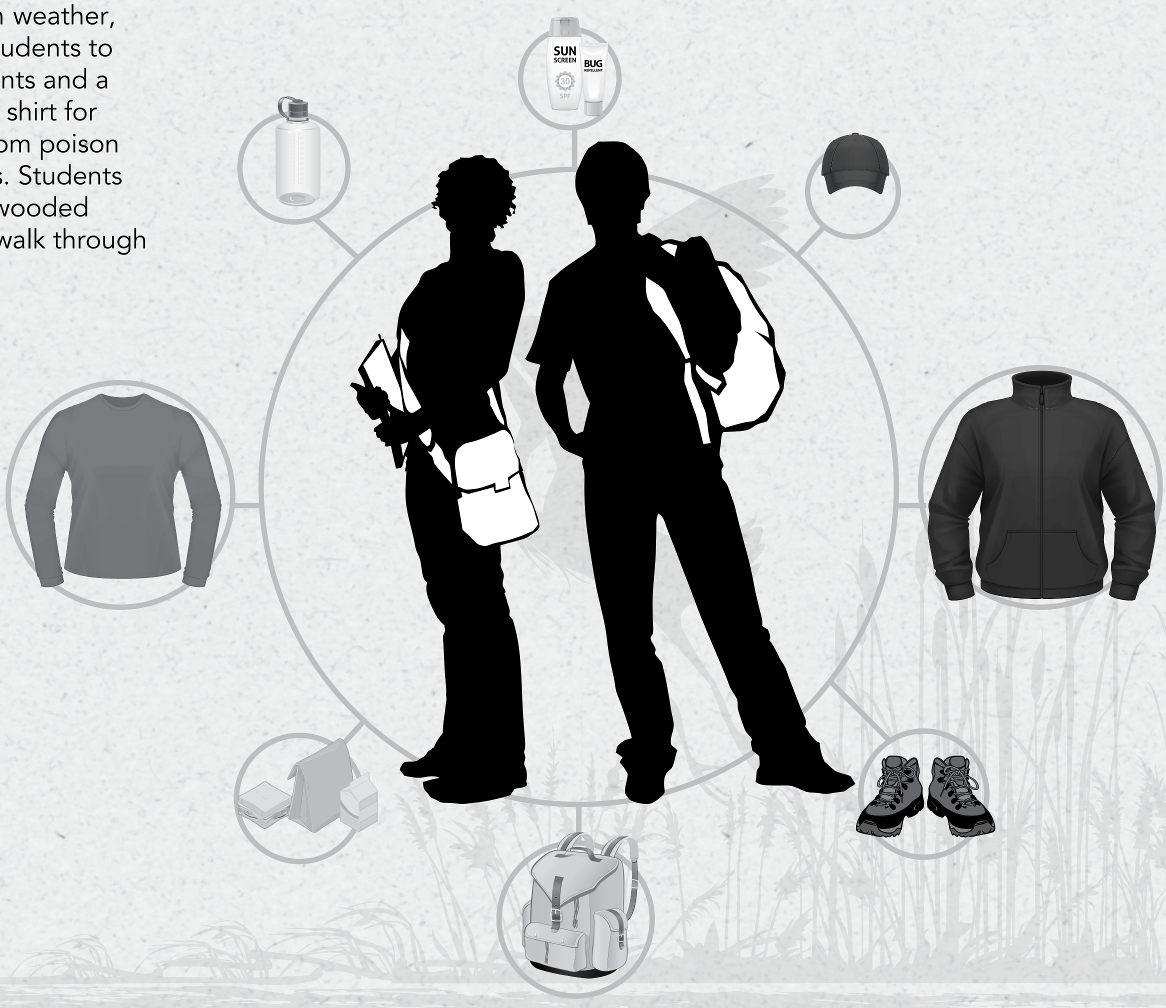
- Keeping in the ecology-minded spirit, suggest that students make their lunch as trash free as possible. Some areas and parks do not have trash cans. What is packed in must be packed out.
- Make sure that students bring sunscreen and insect repellent if desired.

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 briars. Students may be in a wooded area or may walk through tall grass.



What's the Health of the Stream?

EXPLORATION

BACKGROUND INFORMATION:

In this activity, students will work in small groups to explore a stream habitat to assess its health. The AFF educator will facilitate this exploration and provide all materials needed for field investigations. Each student will test the same parameter for which he/she was the "resident expert" in the pre-field study activity, "Understanding the Water Quality Index." This information will be used in a later exercise to prepare a report using the data collected in the park.

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.

Goal:

To determine the water quality of a stream in a local national park.

Class Time:

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

Group Size:

Students will work in the same groups as they did for the pre-field study activity, "Understanding the Water Quality Index."

Materials:

While students will not bring the data sheets to the park, you may want to familiarize them with it in the classroom so they are better prepared when they arrive at the field study.

What's the Health of the Stream?

EXPLORATION

Bridging the Watershed

Watershed Watchdogs 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)

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:

What's the Health of the Stream?

EXPLORATION

Enter the data you collect using the chemistry kits in the fields below:

		You will perform this data analysis in the classroom		
Parameter	**Test Result**	**Q-Value**	**Weighing Factor**	**Total**
Dissolved Oxygen	____mg/L | Water Temp: ____˚C % sat.		0.17	
Turbidity	JTU		0.08	
Phosphates (Orthophosphates)	mg/L		0.10	
Nitrates	mg/L		0.10	
Change in Temperature	___˚C (above) - ___˚C (@ site) = Δ ˚ C		0.10	
Total Dissolved Solids	ppm		0.07	
pH			0.11	
Fecal Coliform	colonies/100 mL		0.16	
BOD	____mg/L | Water Temp: ____˚C % sat.		0.11	
		Overall Water Quality Index		
		WQI Description		

Water Quality Index (WQI) Description	
100-90	Excellent
89-70	Good
65-50	Moderate
49-25	Bad
24-0	Very Bad

Use digital meters to measure these parameters:

Stream Speed	ft/s

Parameter	**Test Result**
Dissolved Oxygen	% sat.
Conductivity (relates to Total Dissolved Solids)	µS/cm
pH	
Change in Temperature	___˚ C (above) - ___˚ C (@ site) = Δ ˚ C

Data Analysis

EXPLANATION

BACKGROUND INFORMATION:

In this activity, each student group will write a summary report assessing the health of the park stream. Focusing primarily on the WQI as an indicator of pollution, each group will use data collected in the park to describe the general health and conditions of the stream.

The BOD and fecal coliform experts will complete their testing and report the results to their group. Each student should record an individual copy of their group's data from the park on the blank data sheets in the student pages. Each team will determine and record the overall WQI and WQI Description. The class will then work together and each student will complete TableV: Class Data for Water Quality Index of the Park Stream.

Using student test results from each group's datasheet, compute a class average from the totals for each parameter. The Overall Water Quality Index will be the sum of the Class Averages computed in Table V.

The total class data should present a more representative picture of the health of the stream because it is a larger sample size. When students compare their group's data with the class data, they may find differences. If a group's data appears very skewed, try to ascertain why before omitting it from the class average.

Data from other classes' field trips can be found on the BTW web site. See the teacher resource page at www.fergusonfoundation.org/btw/teacherresources.shtml for information and instructions on how to access the database.

PROCEDURE:

1. **The experts on BOD and fecal coliform will complete these tests. Enter these data on your datasheet.**

2. **Each person should copy the recorder's data on his/her own blank datasheet.**

3. **Determine the WQI by completing the Overall Water Quality Index of the Park Stream using the procedure described in "Understanding the Water Quality Index."**

4. **Record data from all the groups in Table V: Class Data for Water Quality Index of the Park Stream. Compute the class average for each parameter; then, determine the WQI based on the class average.**

Goals:

- To complete fecal coliform and Biochemical Oxygen Demand (BOD) tests in order to calculate the group's WQI.
- To compute the average WQI for the stream using all class data, not just your group's data.

Class Time:

90 minutes

Group Size:

Same as field study group

Materials:

Student data sheets from the field study.

Data Analysis

EXPLANATION

5. **Each group will use the class data to prepare a report. Begin your report by defining the study area and weather conditions using data from the group's datasheet.**

6. **Using Table V: Class Data for Water Quality Index of the Park Stream, summarize class data for the nine parameters. State the WQI value and its description to assess the health of the stream you studied.**

7. **Note individual parameter values that exceeded significant levels and propose possible reasons (e.g., errors in data gathering, weather conditions, land use affecting the study area).**

8. **The AFF website has additional resources to help you complete your report.**

9. **Complete the Evaluation Form: Performance List. Use this list to evaluate your group's final report, as well as your group's data collection efforts in the park.**

Performance List

EXPLANATION

Group Members ______________________________ Date ______________

Performance Criteria	Assessment		
	Points	Group	Teacher
1 All group data are entered, and an average WQI for the group is accurately determined.			
2 All class data are entered, and an average WQI for the class is accurately determined.			
3 The summary report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data and WQI, a descriptive assessment of the health of the stream is included.			
5 Individual water quality parameters that exceeded significant levels are noted, and possible reasons are proposed.			
6 The summary report is clear, 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, 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:

Polluted Water: Can We Clean It?

ELABORATION

SAFETY WARNING:

Students will be working with a sample of polluted water from the "Who Polluted the Potomac?" activity. Review the following safety procedures with students.

- DO NOT DRINK the polluted water sample before or after it is cleaned.
- BE CAREFUL not to spill the polluted water sample.
- DO NOT ALLOW the sample to come in contact with your skin or clothes.

BACKGROUND INFORMATION:

In "Who Polluted the Potomac?" students demonstrated the effects of nonpoint source pollution on the Potomac River. Now they will think about how to clean up the watershed and the river.

Water from the river must be treated to make it safe for drinking, recreation, fishing, and transportation. In addition, the Potomac River empties into the Chesapeake Bay. Everyone who lives and works in the Potomac River watershed has the responsibility of keeping the river, and ultimately the Bay, as clean as possible.

In this activity, students will explore how water is cleaned to make it safe for human use. This is an open-ended inquiry activity. It is not expected or required that students use all materials listed below to "clean" their water sample.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **"Who Polluted the Potomac?" demonstrated the sources of some Potomac River pollutants. Think about methods you could use to clean this water.**

   Students may think of such ideas as natural filters and aeration in streams, the evaporation and condensation of water, and charcoal filters used in aquariums. Allow students to come up with their own ideas for cleaning the water. They will refine their ideas as they work through the activity.

   Students may need help with some of the scientific terms in the article. If needed, remind them to use the online glossary at fergusonfoundation.org.

Goal:

To design and conduct a procedure to clean a polluted water sample.

Class Time:

90 minutes

Group Size:

Groups of 4

Materials List for Each Group:

- 200 mL of polluted water from "Who Polluted the Potomac?"
- Density separation troughs
- Funnels
- Rubber tubing with pinch clamps
- Filter paper
- Sand
- Straws
- Gravel (pea size)
- Charcoal (available from aquarium stores)
- Paper cups
- Food coloring
- Beakers
- Graduated cylinders
- Gauze or cheesecloth
- Sponge
- Filter
- Floss
- Cardboard
- Baking Soda
- Ferric chloride
- Aluminum sulfate (Alum)
- Stirring rods

Polluted Water: Can We Clean It?

ELABORATION

Special Considerations:

Adequate supplies of all the materials listed should be available for all groups.

2. **Decide what needs to be done to clean the polluted water sample. Discuss your ideas with your team and agree on a cleaning procedure using any of the items from the materials list.**

3. **List the steps in your procedure and run your procedure.**

   The main steps in the process are separation, flocculation, and filtration. Allow students to come up with their own plans, but guide them as needed. Students may want to experiment with the sequence of the steps and materials, and try innovative ways to use the available equipment.

   Some suggested procedures are given below:

   Separation: The first step in municipal water treatment usually involves holding the water in a large basin or lake for a short period of time. This stage allows impurities with different densities to move to different levels in the water sample. Oil products and light materials will float on the surface of the water while dirt and heavier materials will fall to the bottom.

   There are two ways to simulate this action in the laboratory for the purpose of removing liquids that cannot mix with each other as well as some of the undissolved solids. You can use either a trough with a drain at the bottom or a funnel connected to a piece of rubber tubing.

   i. **Using a Trough:** The trough should have a drain tube in the bottom to which you can connect a rubber tube and a pinch clamp. A plastic tub with a hole into which a stopper can fit will also work. The students pour the sample into the trough and allow it to sit there for about five minutes so that the various substances can separate. Substances will take different times to separate because of the differences in their densities. The pinch clamp is then opened, and the level with the cleanest water is allowed to drain through the tubing into a clean beaker. The object is to collect the water and leave the oil and larger particles in the trough.

   ii. **Using a Funnel:** If a trough is not available, a large funnel can be used. Attach a piece of rubber tubing onto the funnel and a place a pinch clamp on the rubber tubing. The students will then pour portions of the sample into the funnel. Each portion should be given time to settle and separate. The pinch clamp is then opened, and the water at the bottom is allowed to drain into a beaker.

   Flocculation: This is the part of the process in which chemicals, such as ferric chloride or aluminum sulfate, are added to the water. These chemicals react with suspended particles to form sticky precipitates. The precipitates stick together to form larger and heavier particles that will sink to the bottom or be filtered out of the water. A scoop of either of these chemicals could be added to the beaker of sample water collected.

   Filtration: To remove suspended particles, odors, tastes, and colorizing agents, the water can be passed through layers of filters. In a large water treatment plant, the filters would be layers of sand, gravel, and charcoal. Students should be reminded that these are the same substances that are used to filter the water in aquariums and are similar to natural filters in streams and rivers.

4. **Students create a data table to record their observations of odor, color, clarity, and volume before and after each step. Approve the students' procedures before they start the cleaning process.**

   When students have completed the procedure, answer the following questions.

Polluted Water: Can We Clean It?

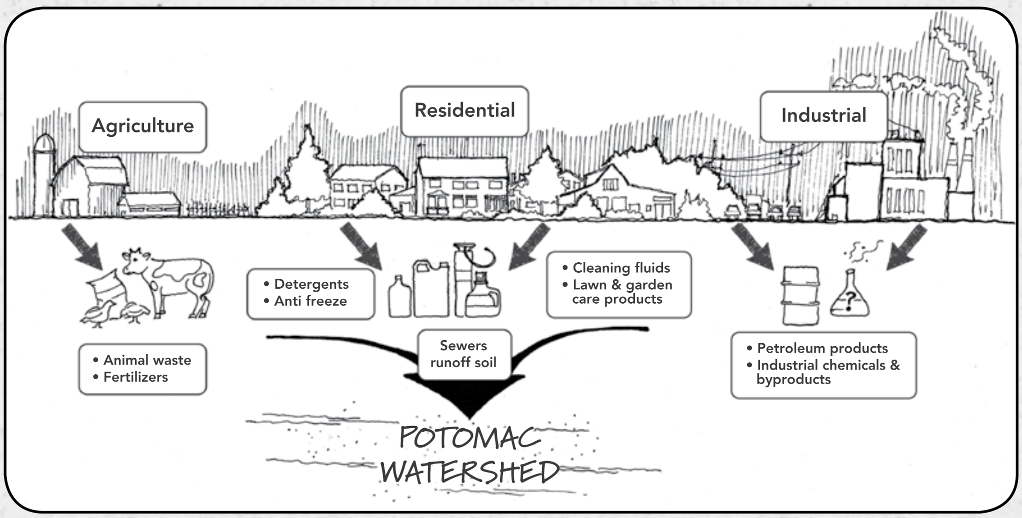
ELABORATION

5. **How many milliliters of water did you lose in the cleaning procedure?**

   Answers will vary.

6. **Calculate the percentage of water remaining at the end of your cleaning procedure.**

   Answers will vary.



7. **Explain why is it important to know how much water is lost during water cleaning.**

   This would be especially important in a large water treatment facility. Clean fresh water is a valuable resource. There is a limited amount of water suitable for use by humans. It is vital that people use water efficiently and recycle what is used.

8. **Is this water suitable for drinking? Why or why not?**

   Students should remember that they could use the tests they performed in the park and with the "Who Polluted the Potomac?" activity. They could test the pH, phosphates, nitrates, turbidity, and total dissolved solids. Acceptable levels for these tests are provided in your resource materials. Students should also look for apparent color and odor.

9. **If you had to repeat this procedure what would you do differently?**

   Answers will vary but should demonstrate that the student recognized parameters that could be improved or ways to reduce the loss of sample in the cleaning process.

10. **Compare the apparent color, odor, pH, orthophosphates, nitrates and turbidity reading for the three trials.**

11. **What "factor" do you think affected the apparent color, odor, pH, orthophosphates, nitrates and turbidity? Why?**

12. **What cleaning procedure do you think worked best for apparent color, odor, pH, orthophosphates, nitrates and turbidity? Why?**

13. **Could the cleaning procedure be adapted to clean water on a large scale?**

14. **Read "Imitating Nature to Clean Our Water" in the Resources to find out how pollutants are removed from municipal water. Discuss the article with your team members to help you determine how to remove undissolved solids, immiscible liquids, odors, and colors with minimal water loss.**

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 heighten students' awareness and help them understand the important role they play in the health of their watershed. The choices they make about how to interact with their environment 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 the Ferguson Foundation website to find information on how to take on a watershed action project. We provide some step-by-step instructions, but students provide the inspiration and execution.

Goals:

- To increase awareness of the need for individual environmental action.

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 BTW website and check out our detailed guide on organizing a student-led conservation project.

Resources

Why Should We Be Concerned About Clean Water?

Adapted from: A Brief History of the Clean Water Act

Most forms of life on Earth require clean water and cannot survive without it. Though the supply used to be plentiful, the situation changed over time so that, by the 1970s, at least 65% of the water tested in U.S waterways was unsafe for fishing or swimming because of pollution. The U.S. Congress was so concerned that it passed the Clean Water Act in 1972. The goal of the act was to provide all Americans with waterways safe enough for swimming and fishing. With the act, we rejected some old ideas and practices that led to widespread water pollution, decided to clean up the pollution already present, and made a commitment to keep the waterways clean using good resource management practices.

Today, only about 33% of this nation's waters are considered unsafe for fishing and swimming. That's some improvement, but not enough, and many of those "safe" areas are now threatened by new sources of pollution. Most of the pollution we've been able to eliminate is from traceable sources like a factory or a sewage treatment plant. This type of pollution is called "point source pollution" because we can point to one place - one point - as the source of the problem. Unfortunately, most of the really damaging pollution is untraceable because it comes from multiple sources, reaching the waterways in runoff. When it rains, whatever is on the land washes into rivers, lakes, and oceans. Wetlands, stream corridors, and coastal areas are especially vulnerable to this type of pollution, called "nonpoint source pollution." It's a deadly combination of substances, including various pollutants from urban and suburban streets and parking lots, fertilizers and pesticides from lawns and farms, and other substances from forestry, ranching, and mining operations. All these runoff pollutants threaten environmental balance as well as human health. Every year, there are more warnings for people not to use certain beaches or eat certain fish or shellfish because of pollution. New threats to health such as the microorganism Pfiesteria arise as a consequence of new or continued pollution.

The United Nations recognized the connection between land use and clean water as an environmental crisis. In 1992, the General Assembly of the UN invited all countries on Earth to a conference in Brazil to discuss the problem. The leaders at this conference understood that all of us in the rapidly rising world population are trying to improve our standard of living. As we do so, we destroy the environment at an alarming rate. We clear land for new housing, transportation, growing food, and manufacturing, and we pollute. This disrupts many natural cycles like the water cycle, food chains, and O_2/CO_2 cycles, and it reduces the supply of clean water for all organisms on Earth. The participants addressed the global question of how to allow for development while maintaining the natural ecosystems. They knew about the "interconnectedness" of all life on Earth and agreed that development must be balanced by environmental protection. They understood that if we fail to do this, there would soon be nothing left to develop. Humans cannot survive if the delicate balance of ecosystems on Earth is destroyed.

The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value.

—Theodore Roosevelt

Dissolved Oxygen (DO)

For a body of water to be considered "healthy," it must have enough dissolved oxygen (DO) to support organisms such as fish, invertebrates, plants and aerobic bacteria. They all require oxygen for cellular respiration, just as humans do. People have noticed that aquatic animals often suffer from lowered DO levels in the late nights and early mornings during a summer heat wave. Read the information below to find out why.

SOURCES OF DISSOLVED OXYGEN

Much of the DO in water comes from the atmosphere because gaseous oxygen dissolves at the surface where air and water meet. Disturbance of the surface by rainfall, wind, or movement over rocks (such as rapids and riffles) causes more oxygen to dissolve. The more the water churns and bubbles, the more oxygen gets mixed with the water and dissolves in it. Another source of DO is the oxygen that aquatic plants and phytoplankton (including algae) produce during photosynthesis.

PHYSICAL INFLUENCES ON DISSOLVED OXYGEN

DO levels rise and fall with the season as well as with the time of day. The general rule is that warm water holds less oxygen than cold water, so the same body of water has a lower DO level when it's warm than when it's cooler. Water also holds less oxygen at higher altitudes, so on a given day, a lake at the top of a mountain would contain less oxygen than an otherwise similar lake at the bottom of the same mountain.

Aquatic plants need light to produce oxygen, so DO levels are usually low whenever light is low. This includes nights, cloudy days, and whenever dense algal growth blocks sunlight. People decrease DO whenever we do anything that causes water to be warmer than normal. Sometimes we use water to cool machinery in a factory or power plant and then return the water to a waterway. The water that is returned is warm because of the heat it absorbed from the hot machinery, so it can't hold much oxygen. This produces "thermal pollution," a problem causing major changes in aquatic ecosystems worldwide.

UNITS OF MEASUREMENT FOR DISSOLVED OXYGEN

We measure DO either in milligrams of oxygen per liter of water (mg/L) or in parts per million (ppm). We can also convert those amounts to percent (%) saturation.

HOW MUCH DISSOLVED OXYGEN IS ENOUGH?

Different aquatic species require different amounts of oxygen for healthy survival. Some species require different amounts at different life stages (such as tadpole versus adult frog). However, in most cases, bodies of water with consistently high levels of DO (90 % saturation or higher) are considered healthy. That means they are stable and capable of supporting many different kinds of aquatic life.

Dissolved Oxygen levels of:

>5 – 6 mg/L or 80 - 125% saturation are sufficient for most species.

< 3 mg/L or 60 - 79% saturation are stressful to most aquatic species.

< 2 mg/L or < 60% saturation are fatal to most species.

If DO levels fall, organisms that can move (like fish and some types of invertebrates) leave the low DO areas and congregate in areas with higher levels of oxygen. This temporary increase in population may deplete the food or oxygen in the new area, further compounding the problem. Organisms that can't move (like oysters), move too slowly (like clams), or are trapped (like crabs in a crab trap) usually die when DO levels fall below their oxygen requirements.

Fecal Coliform

In June 1998, 13 toddlers developed a serious Escherichia coli infection after a day of fun in a local swimming pool. It was later determined that a child had defecated in the pool. Though none of the children died, five were hospitalized, two in critical condition. This mode of infection was unusual for E. coli, since it is usually passed when people eat contaminated meat that has been undercooked or eat contaminated fruits and vegetables that have been inadequately washed.

Fecal coliform bacteria (most commonly Escherichia coli, abbreviated E. coli) are found naturally in the lower intestine of many vertebrates, including humans. They aren't found in water unless intestinal wastes (feces) have contaminated the water, so their presence in water is a reliable indicator of fecal contamination. Fecal coliform bacteria don't usually cause disease, but many other types of organisms present in sewage do. It's much easier to test for E. coli than for all the other possible types of fecal coliform. Therefore, E. coli can be used to warn us about the possible presence of those other pathogenic (disease-causing) organisms.

HOW FECAL COLIFORM RESULTS ARE EXPRESSED

The results of tests for coliform bacteria in water are expressed as the number of bacterial colonies per 100 milliliters (mL) of water.

SIGNIFICANT LEVELS

Because of nonpoint source pollution, most untreated water contains low levels of coliform bacteria. Water treatment facilities monitor these levels. Factors such as water temperature, DO levels, and speed of stream flow can all affect bacterial levels, making it difficult to maintain steady water quality. For this reason certain levels of coliform bacteria are "allowable" in water. Though we might prefer that all our water be 100 % free of bacteria, some of the things we use water for, like flushing toilets, need not be the same quality as the water we use for drinking. There are three levels of water usage: drinking water, primary contact (such as swimming), and secondary contact (such as washing vegetables intended for human consumption). Refer to the chart below. High levels of bacteria indicate water that is unsafe for human contact of any kind.

Water usage	Desirable numbers of bacteria colonies per 100 mL of H2O	Acceptable numbers of bacteria colonies per 100 mL of H2O
Drinking water	0	0
Primary contact	< 200	< 1,000
Secondary contact	< 1,000	< 5,000

pH

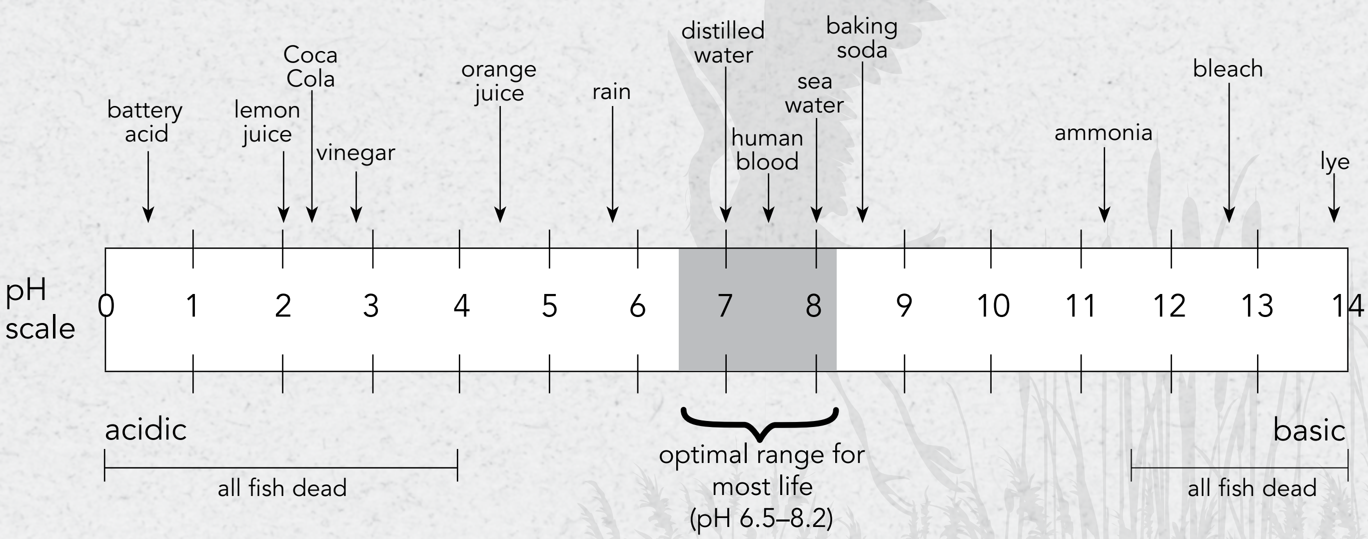
The pH test is one of the most common variables used in water testing. What we call acidity is really a measure of the hydrogen ion (H+) concentration in the sample. pH ranges from 0 - 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids, and those with a pH above 7.0 are considered bases. Most rainwater has a pH of about 5.6. The chart below shows the pH of common substances and pH limits for aquatic organisms.

SIGNIFICANT LEVELS

Though different aquatic organisms have a different optimal pH, most can tolerate anything between 6.5 and 8.5. Many chemical and biological processes are affected by pH. A pH level outside this range can reduce the diversity in the stream because it stresses the body systems of most organisms and can reduce their reproductive success. Many factors can affect the acidity of aquatic ecosystems. Some of these are acid rain, minerals that dissolve out of rocks, melting snow, heavy precipitation, accidental spills, agricultural runoff, and sewer overflow. Organisms themselves may also affect the pH. The more dissolved CO_2 there is present in water, the more acidic the pH becomes (pH decreases). Photosynthesis by aquatic plants removes dissolved CO_2, so waterways with growing plants often show an increase in pH during the growing season and a decrease when the plants die. This is especially true if the water is still or slow-moving. Organisms living in these areas must be able to either adapt to the fluctuations or move in order to survive. Low pH (acidity) can also make toxic substances more mobile and easier for aquatic plants and animals to absorb. Some species like rainbow trout are more sensitive than other species to this toxic condition.

MEASURING pH

Simple test kits are used to measure pH. Test the pH of a sample immediately because pH may quickly change due to biological and chemical activity in the sample container. The pH is expressed as a number from 1 to 14, including tenths (e.g., 6.7).



Biochemical Oxygen Demand (BOD)

Most organisms require oxygen, including the bacteria that decompose organic matter. When aerobic bacteria decompose organic material, they break it down by oxidation (combining with oxygen). BOD is an abbreviation for biochemical oxygen demand, a measure of how much oxygen these bacteria use in the aerobic oxidation of organic matter. Some pollutants such as inadequately treated sewage are organic, and bacteria use oxygen dissolved in the water to decompose them. For more information about dissolved oxygen, refer to page 31 of the Resources.

MEASURING BIOCHEMICAL OXYGEN DEMAND

We measure BOD by comparing the amount of dissolved oxygen present in a freshly collected water sample with the amount of dissolved oxygen in a second sample collected at the same time and place but allowed to "sit" for five days under special conditions so that the bacteria in the sample have time to work. The difference between the dissolved oxygen in the two samples is how much oxygen the decomposing bacteria used to oxidize the organic material in the water during the 5-day incubation period. The amount of dissolved oxygen used over 5 days is the BOD.

SIGNIFICANT LEVELS

The BOD of unpolluted, natural waters is 5 mg/L or less. Since very little oxygen is being used, there is plenty available for a variety of aquatic organisms. If a lot of organic material is added to the water, the BOD increases, (that means there is a high demand for oxygen, specifically by bacteria that are decomposing organic matter). Raw sewage may have a BOD level of 150 to 300 mg/L. When aerobic bacteria use up a lot of the dissolved oxygen, little is left for other aquatic organisms. Wastewater treatment plants must reduce BOD to levels specified in their discharge permits. These levels vary according to area, but they are usually between 8 and 150 mg/L, with most permits specifying about 30 mg/L BOD so that aquatic life isn't threatened with suffocation.

Water Temperature

HOW IS TEMPERATURE IMPORTANT TO THE HEALTH OF A RIVER?

Temperature affects many of the chemical properties of water itself, as well as many biological and physical processes within the aquatic ecosystem. Among other things, temperature affects the:

1) oxygen content of the water (oxygen levels become lower as temperature increases)
2) rate of photosynthesis by aquatic plants
3) metabolic rates of aquatic organisms
4) sensitivity of organisms to toxic wastes, parasites, and diseases.

Acceptable temperatures vary from site to site and season to season. In general, however, temperatures above 27° C (80.6° F) are unhealthy.

HOW IS WATER TEMPERATURE IMPORTANT TO AQUATIC ORGANISMS?

Water temperature is one of the key factors determining what species are best suited to certain regions. Different species of fish and other aquatic organisms have different optimal temperatures, some surviving best in colder water, others in warmer water. Refer to the following chart for temperature ranges.

Range description	Celsius	Fahrenheit
Warm	20° - 25°	68° - 77°
Cool	13° - 19°	55° - 67°
Cold	5° - 12°	41° - 54°

If temperatures are outside a species' optimal range for a long period of time, organisms become stressed and often die. More sensitive species can be weakened by even a short "temperature shock" and become more subject to disease or parasitism as a result. Water temperature affects metabolism in aquatic animals as well as many behaviors, including general activity, feeding, and reproduction. A week or two of high temperatures each year may make a stream unsuitable for sensitive organisms, even though temperatures are within tolerable levels throughout the rest of the year.

WHAT CAUSES CHANGES IN WATER TEMPERATURE?

Obviously, natural processes such as changing weather and groundwater flowing into waterways can cause temperature changes, but many things that people do can also cause it. We cause temperature change when we do things such as:

1) remove stream bank vegetation that shades the water
2) impound water (when we confine it, like with a dam)
3) discharge water we heated by using it to cool something
4) channel water from impervious urban surfaces which heats water going into storm drains that flow into rivers.

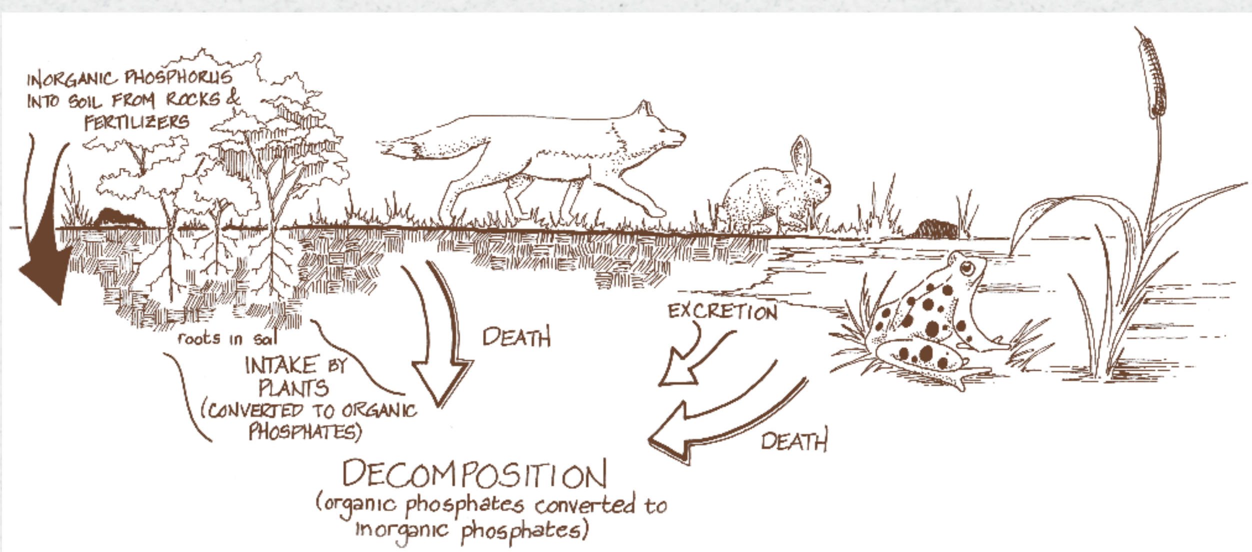
WHAT ARE ACCEPTABLE CHANGES IN WATER TEMPERATURE IN A ONE - MILE REACH?

A change of more than 4 or 5 degrees Celsius in less than a one-mile length of the stream indicates a source of thermal pollution or a significant change in the tree canopy shading a stream. Both causes will degrade the quality of the aquatic habitat.

Phosphates:

Phosphorus is essential for life. When phosphorus combines with four oxygen atoms, it forms a phosphate ion. Phosphate that is not combined in any molecules in plants or animals, making it available for reaction, is called "orthophosphate," meaning "straight phosphate." Algae and larger aquatic plants rapidly take up this ion because they need it for many metabolic reactions and for growth. Animals need it for similar reasons, and they get the phosphates they need from the food chain. Not only is orthophosphate the reactive form of phosphate, but it is also much easier to test for this form than other phosphate forms. In most natural bodies of water, orthophosphate is present in very low concentrations. Though nitrogen is more important to plants, there is usually plenty of it available. Therefore, the less available phosphorus acts as the "growth-limiting" factor for producers because plants compete for it, and plant growth and reproduction will be limited by the amount available.

Algae are individually microscopic and require only small amounts of phosphate. When excess amounts of orthophosphates are available, algae reproduce rapidly in population explosions called algal blooms. The most common reasons for excess orthophosphates are things people do. We use manufactured substances that contain large amounts of phosphates, such as fertilizers for our lawns or crops, detergents with phosphate water softeners, and some industrial wastes. Much of these end up being washed into storm drains. We also allow natural substances that are rich in phosphates, such as human or animal wastes, to get into the water. Algal blooms are a clear indication of what we call "cultural eutrophication," human–caused enrichment of water with nutrients. When you test the water for phosphates, you are actually testing for the uncombined or reaction-available form: orthophosphates.



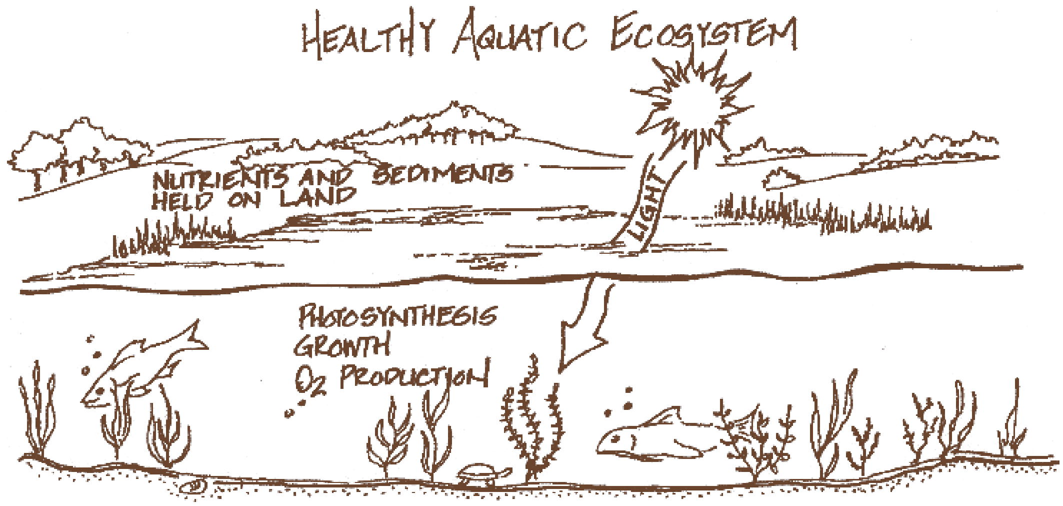
IMPACTS OF CULTURAL EUTROPHICATION

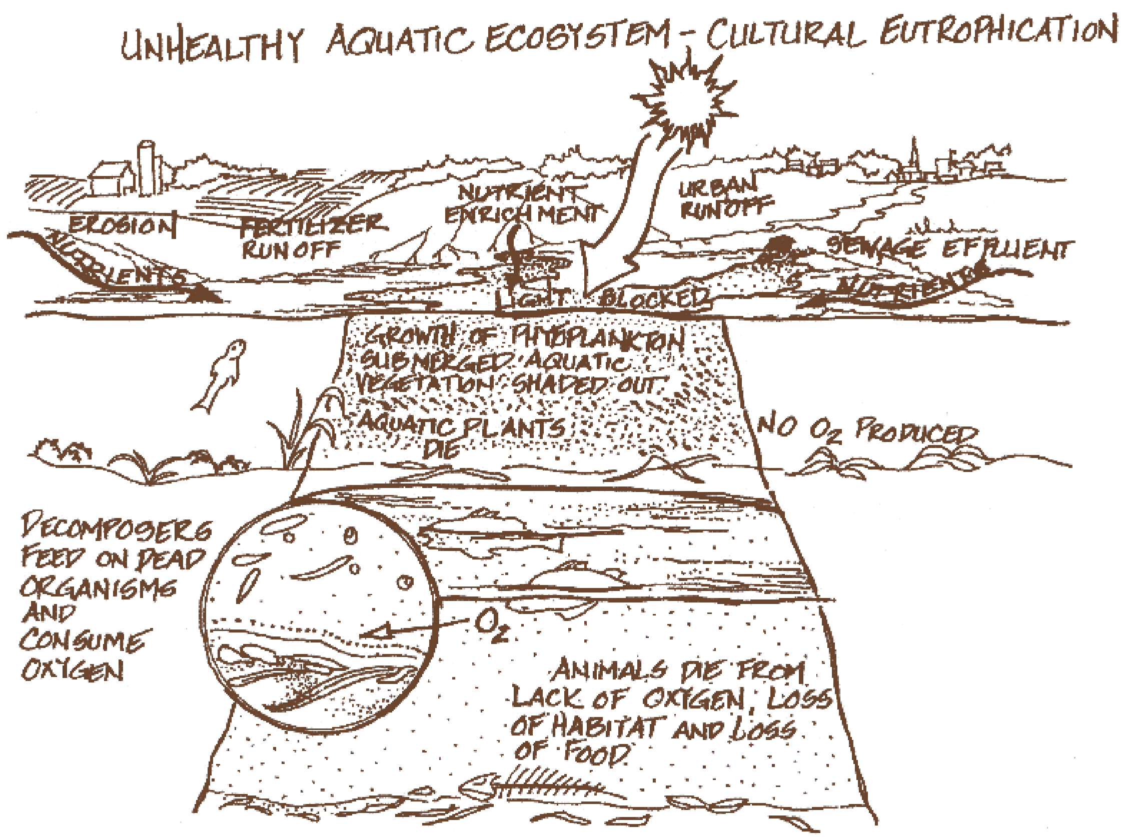
Eutrophication is a natural cycle that is supposed to take thousands of years. Cultural eutrophication, what we cause, is so accelerated that it can occur in years or months, quite possibly resulting in the death of an entire ecosystem. The first sign of cultural eutrophication is usually an algal bloom that makes 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.

This "kill" provides a great deal of organic material for bacteria to decompose. Since the bacteria use oxygen in this process, dissolved oxygen in the water decreases, and aquatic animals must either move out of the area or die. These conditions usually occur near the bottom of a lake or impounded river stretch, and produce gases like hydrogen sulfide, unmistakable for its "rotten-egg" smell.

SIGNIFICANT LEVELS

In natural bodies of water, an orthophosphate level of 1.0 mg/L is considered excellent. Levels of 2-3 mg/L contribute to increased plant growth and algal blooms, and levels of 4.0 mg/L and higher may temporarily stimulate plant growth enough to surpass natural eutrophication rates.





Nitrates

Both plants and animals need nitrogen to build protein and nucleic acids. In nature, nitrogen is much more abundant than phosphorus and is most commonly found in its molecular form (N_2) in the atmosphere. In fact, it makes up about 79% of the air we breathe, but this form of nitrogen is useless to both plants and animals.

A certain amount of nitrogen gets into water by natural processes. Some types of bacteria and some algae are able to convert N_2 into ammonia (NH_3) and nitrate (NO_3^{-1}) that plants can use for growth. Animals get nitrogen by eating plants or other animals that feed on plants, both on land and in water. Waste from these animals decomposes, and the nitrates are recycled. When these organisms die, all the nitrogen in their bodies reenters the nitrogen cycle. Similarly the excrement from ducks and geese contributes a heavy load of nitrogen to areas where these animals are plentiful.

OTHER SOURCES OF NITRATES

Though a certain amount of nitrogen is necessary in aquatic ecosystems, too much can cause problems. Humans are responsible for some of the excess nitrates in water. Runoff from the land can contain fertilizers, sewage from leaky cesspools or sewage treatment plants, manure from livestock, and nitrates from car exhaust – all contain significant amounts of nitrogen. Increased levels of nitrogen are evident after a storm. The presence of nitrates in water during dry weather is an indication of direct drainage of sewage or manure into waterways.

SIGNIFICANT LEVELS

Nitrates dissolve more readily in water than phosphates do. Thus, they tend to accumulate more quickly in bodies of water than do phosphates. Unpolluted water generally has a nitrate level below 4.4 mg/L. Nitrate levels above 4.4 mg/L indicate unsafe drinking water.

Nitrate contamination of groundwater is a major concern, especially in regions where large amounts of agricultural fertilizers are applied. Though nitrate itself does not cause any health problems, it is converted to nitrite when ingested, and nitrites may be quite harmful. Nitrate levels in the "unsafe" range convert to nitrites that are believed to cause hypoxia (low level of oxygen) in warm-blooded animals. Though the research is not conclusive, the ingestion of nitrite may be especially dangerous to unborn babies in the first three months of life, making the presence of nitrates in groundwater of special concern to pregnant women. Nitrites may be a cause of "blue baby syndrome" (methomoglobinemia), a potentially fatal condition.

Turbidity

Turbidity is cloudiness. Cloudy or turbid water contains suspended solids such as soil particles (clay, silt, and sand), plankton, including algae, and various microbes. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand), large enough to block some of the light rays and reduce the amount of light that can pass through. The higher the turbidity, the less light passes through to the plants living under water. Dissolved substances don't generally contribute to turbidity. (For a discussion of total dissolved solids, refer to page 40.)

HOW TURBIDITY AFFECTS THE ENVIRONMENT

Turbidity causes higher water temperatures because the suspended particles absorb heat. This reduces the amount of dissolved oxygen (DO) in the water because warm water holds less oxygen than cold water does. Because higher turbidity reduces the amount of light passing through the water to aquatic plants, photosynthetic activity is reduced, and less oxygen is produced. This further reduces the DO. Suspended materials can also clog the gills of fish and other animals.

Since the animals get less oxygen, their body systems are stressed, their resistance to disease is lowered, and their growth rates are reduced. The sediments can also interfere with the development of their eggs and young. Particles of sediment may even smother fish eggs and benthic macroinvertebrates.

WHAT ARE THE SOURCES OF SEDIMENTS THAT CAUSE TURBIDITY?

- **EROSION.** Soil particles are the most common cause of high turbidity. Normally, plant roots hold soil in place and absorb rainwater. Many human activities remove the soil's protective plant cover, and the soil washes or blows away. Construction companies often leave large areas of exposed soil. Farmers may leave fields unplanted after a harvest. Timber companies cut down trees to make lumber or paper, and new trees take years to grow. Rain on any of these areas picks up soil and carries it into streams or rivers. The fewer plants there are, the less water gets absorbed and the faster the water flows off the land. The larger volume of water causes streams to flow faster. Faster flowing streams erode their own banks, increasing the sediments in the water. This causes a sharp rise in the turbidity of the stream. Dry weather causes a different kind of erosion problem: wind carries the dry dirt into streams.

- **WASTE MATERIALS.** Waste materials from factories, towns, and cities may get into the water by accident, or deliberately if the waterway is used as a convenient "dump." Even natural materials such as leaves and grass can increase turbidity if they are dumped into these waterways and begin to decay.

- **IMBALANCE IN THE ECOSYSTEM.** Various types of imbalance can increase turbidity. If disturbance of the ecosystem has eliminated all but the most pollution-tolerant species of fish (such as carp), their numbers will increase. Large numbers of bottom feeders like carp stir up sediments. Nutrient imbalance may cause eutrophication, encouraging the overgrowth of algae populations. In this case, the cloudiness in the water looks green.

SIGNIFICANT LEVELS

Drinking water should have a turbidity less than 0.5 Jackson Turbidity Units (JTU). Typical groundwater is considered acceptable with a turbidity of anything less than 1.0 JTU. In a stream, turbidity higher than 40 JTU can damage gills and interfere with the ability of fish to find food.

Total Dissolved Solids (TDS)

Each body of water contains a unique mixture of dissolved materials. Total dissolved solids (TDS) is the amount of material dissolved. The composition depends mainly on the solubility of the substances in contact with the water, including soils and rocks along the waterway. We can measure TDS by filtering the water (to take out suspended solids) and evaporating the water from the filtrate. What was dissolved in the water sample will be left behind. We can also measure the electrical conductivity of the water because many dissolved solids increase conductivity.

SOURCES OF TDS

Human activity increases TDS in natural waterways. Runoff from urban areas carries salt from the streets, fertilizers from lawns, and many other materials. Wastewater treatment plants can add phosphorus, nitrogen, and dissolved organic matter.

SIGNIFICANT LEVELS

Rainwater has very little dissolved in it, so it has a low TDS level of < 10 mg/L. Rivers typically contain between 100 and 2,000 mg/L dissolved material. Municipal water systems try to achieve <500 mg/L TDS for drinking water. Higher TDS levels give water a mineral taste and can cause the water to have a laxative effect.

CHANGES IN AQUATIC LIFE

Aquatic life depends upon a constant TDS level for a variety of reasons. For example, dissolved calcium affects how easily water can flow into and out of an organism’s cells. High TDS can cause water balance problems for organisms. Low TDS concentrations may limit growth of aquatic life. Phytoplankton and floating aquatic plants, for example, absolutely require the nitrates and phosphates dissolved in the water because they have no roots to take up those nutrients.

Apparent Color and Odor

APPARENT COLOR

The apparent color of water is the result of both dissolved substances and suspended materials, so color can provide useful information about the water's source and content. Pure water absorbs various wavelengths of light at different rates. Blue light and blue-green light are the wavelengths best transmitted through water, so a white surface under pure water appears blue. Natural metallic ions, plankton, including algae, industrial pollution, and plant pigments from humus and peat may all produce different 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 or dinoflagellates
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. Municipal or industrial wastes, decomposing plants, or microbial activity can also cause odor. 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

Determining the Maximum Percent Dissolved Oxygen at Various Water Temperatures

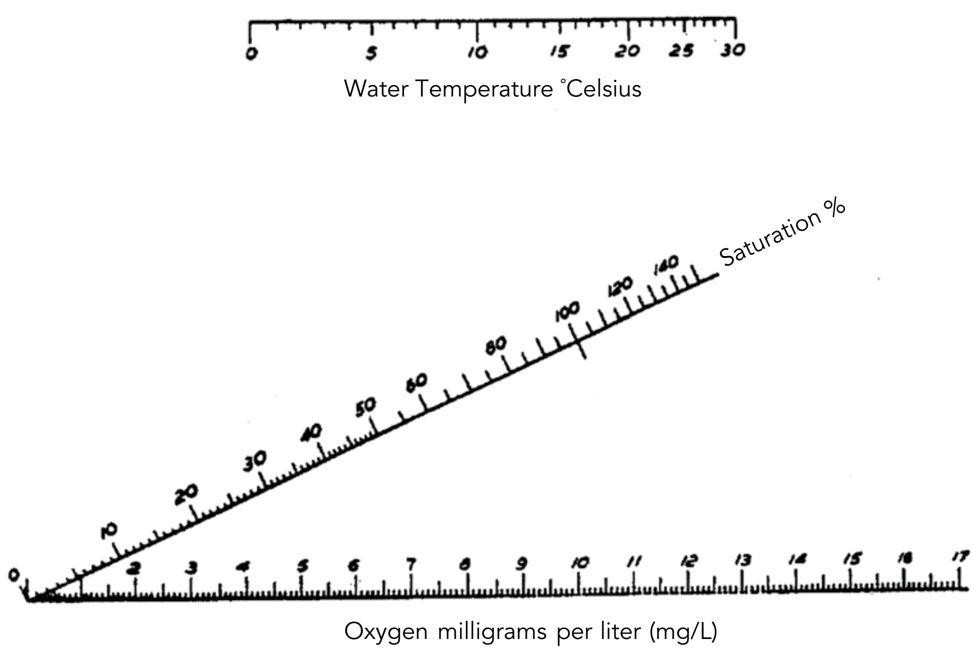
1. **Complete the DO test to determine milligrams of oxygen per liter of water.**

2. **Record the temperature of the water where you collected your sample in degrees Celsius.**

3. **Correct your DO value (mg/L) for atmospheric pressure by multiplying your value by 0.98. (This is the correction value for the Washington metropolitan area.)**

4. **Determine the maximum percent dissolved oxygen using the graph below:**
   a. Find the water temperature value on the top scale.
   b. Find the DO reading in mg/L on the bottom scale.
   c. Draw a line between these two points.
   d. Where the line crosses the sloping saturation scale is the maximum DO percentage.

MAXIMUM PERCENT DISSOLVED OXYGEN AT VARIOUS WATER TEMPERATURES



Weighting Graphs to Determine Q-Values

Q- VALUES: A MEANS OF WEIGHTING WATER QUALITY TEST VALUES

To develop the WQI, the National Sanitation Foundation selected 142 people who represented a wide range of positions at the local, state and national level. Through a series of questionnaires, each panelist was asked to consider 35 water quality tests for possible inclusion in an index. This number was finally reduced to the nine tests currently used.

The scientists were then asked to graph the level of water quality ranging from 0 (worst) to 100 (best) from the raw data for each of the tests. For example, for stream health, the best value for pH is about 7.4, so it is given a Q-value of close to 100. Low and high pH values do not support stream health and were given lower scores. The curves drawn by each scientist were then averaged to obtain a weighting curve for each parameter. Results of the nine parameters are compared to the curves, and a numerical value, or "Q-value" is obtained. These curves represent the best professional judgment of the 142 respondents to an arbitrary scale of water quality from 1 to 100.

COMPUTE Q-VALUES FOR EACH PARAMETER AS FOLLOWS:

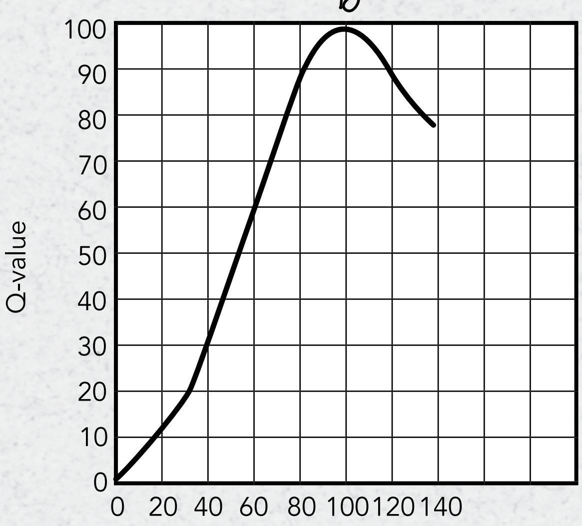
a. Find the weighting curve graph for your test.

b. Mark your test result with a pencil on the X-axis (horizontal) of the weighting curve graph.

c. Draw a vertical line from that point to the weighting curve. Then draw a line from the intersection point on the curve to the Y-axis (vertical) of the graph. The point where your line intersects the Y-axis is the Q-value for your test result.

Resources

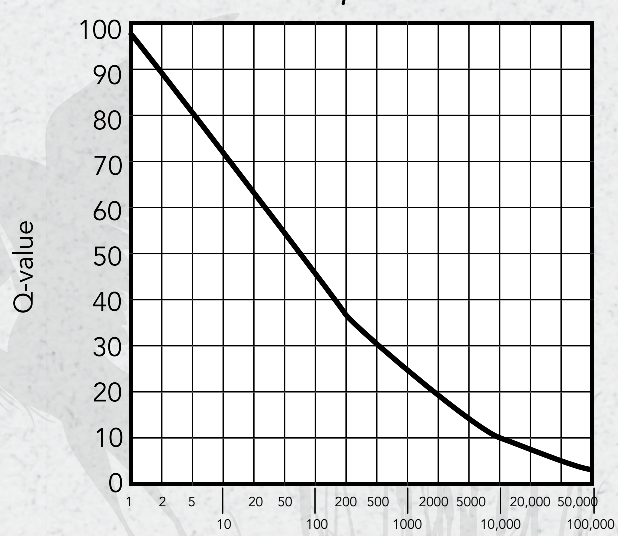
1. Dissolved Oxygen Test Results



Dissolved Oxygen: % Saturation

Note: Q = 50.0 if DO% saturation >140.0

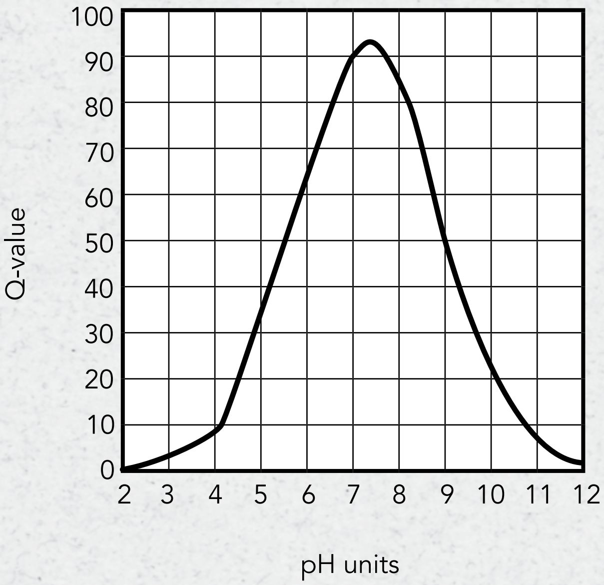
2. Fecal Coliform Test Results



Fecal Coliform: colonies/100 mL

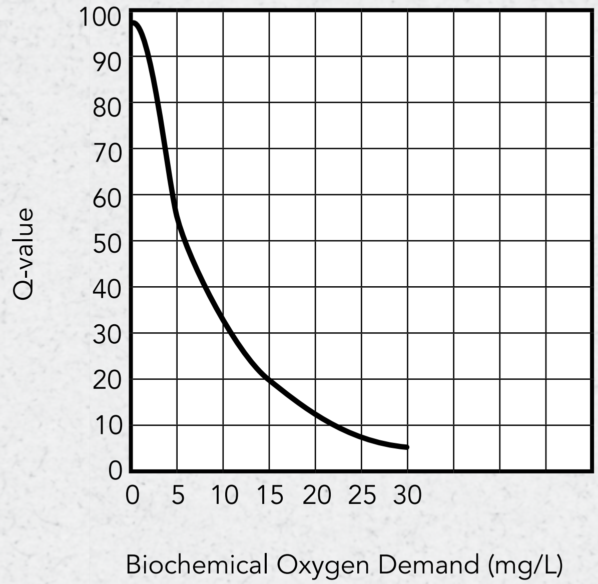
Note: Q = 2.0 if Fecal Coliform >100,000

3. pH Test Results



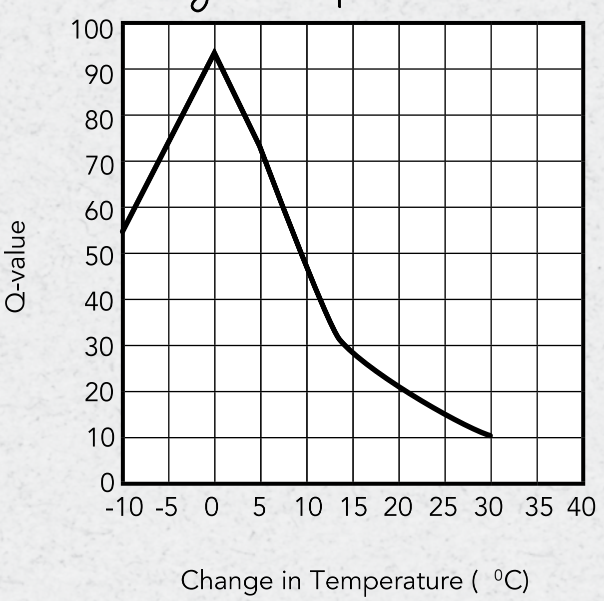
Note: Q = 0.0 if pH <2.0 or if pH >12.0

4. Biochemical Oxygen Demand Test Results

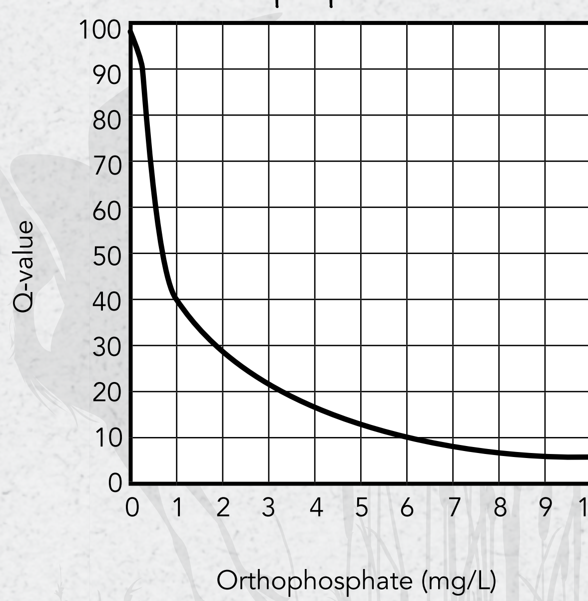


Note: Q = 2.0 if Biochemical Oxygen Demand >30.0

5. Change in Temperature Test Results

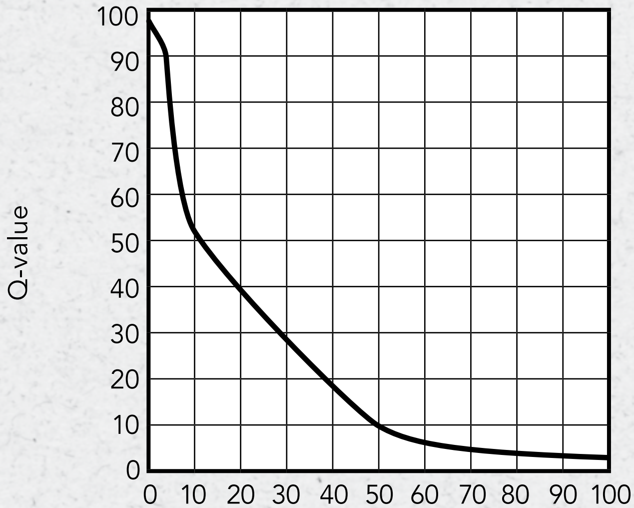


6. Orthophosphate Test Results



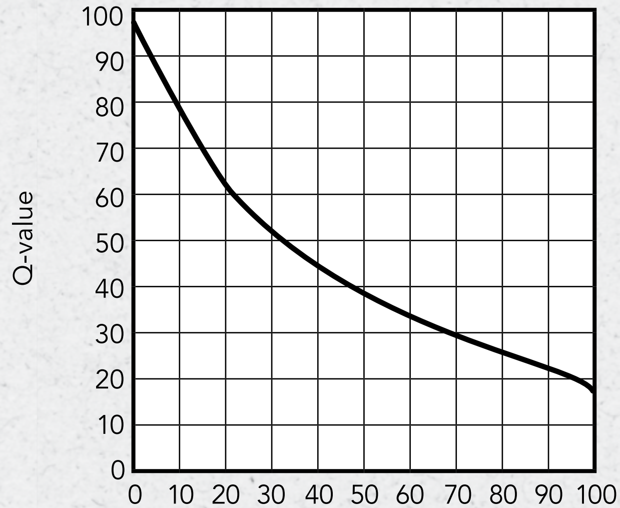
Note: Q = 2.0 if orthophosphate >10.0

7. Nitrate Test Results



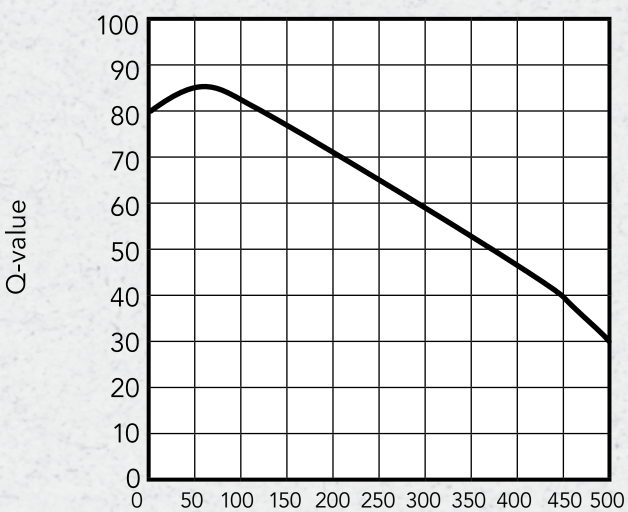
Nitrate (mg/L)
Note: Q = 1.0 if Nitrate >100.0

8. Turbidity Test Results



Turbidity (JTU)
Note: Q = 5.0 if Turbidity >100.0

9. Total Dissolved Solids Test Result



Total Dissolved Solids (mg/L)
Note: Q = 20.0 if Total Dissolved Solids >500.0

Imitating Nature to Clean Our Water

You have learned how to test water for the nine parameters of the WQI used to indicate the health of rivers. Water is naturally recycled and cleaned in the hydrologic (water) cycle. In this process, water evaporates from bodies of water to form clouds of water vapor. The water vapor in the clouds cools, condenses back into liquid, and falls to Earth as precipitation. Humans imitate this process by cleaning water through distillation. In distillation, water is boiled. Only the water evaporates, leaving the impurities behind. The water vapor, almost completely free of impurities, is then cooled and allowed to condense back to water that is now clean.

Another way people imitate nature's water cleaning processes is by treating water in various ways at water treatment plants (see drawing of filtration plant on page 47). In the Washington area, people use about 450 million gallons of water every day. Most of the water used comes from rivers in the Potomac watershed. The water is captured in human-made lakes and reservoirs. To ensure the high quality of the water, it is piped to filtration plants. A treatment plant is a series of buildings that contain mixing tanks, settling basins, and filters. Raw or untreated water is pumped into the plant, where it is converted into high-quality water suitable for human use through a seven-step process: coagulation, flocculation, chlorination, settling, filtration, corrosion control, and flouridation. These steps are described below.

1. **SEPARATION**– The first step in municipal water treatment usually involves holding the water in a large basin or lake for a short period of time. This stage allows impurities with different densities to move to different levels in the water sample. Oil products and light materials will float on the surface of the water while dirt and heavier materials will fall to the bottom.

2. **COAGULATION** – As raw water enters the plant, lime and a coagulating chemical — ferric chloride or alum (aluminum sulfate) — is added. These chemicals react with the water to form a sticky precipitate that traps any suspended particles. These particles may be a variety of substances (see Turbidity, page 39).

3. **FLOCCULATION**– The water is gently mixed. Small sticky particles clump together to form larger particles called "floc" that are heavier and will sink to the bottom.

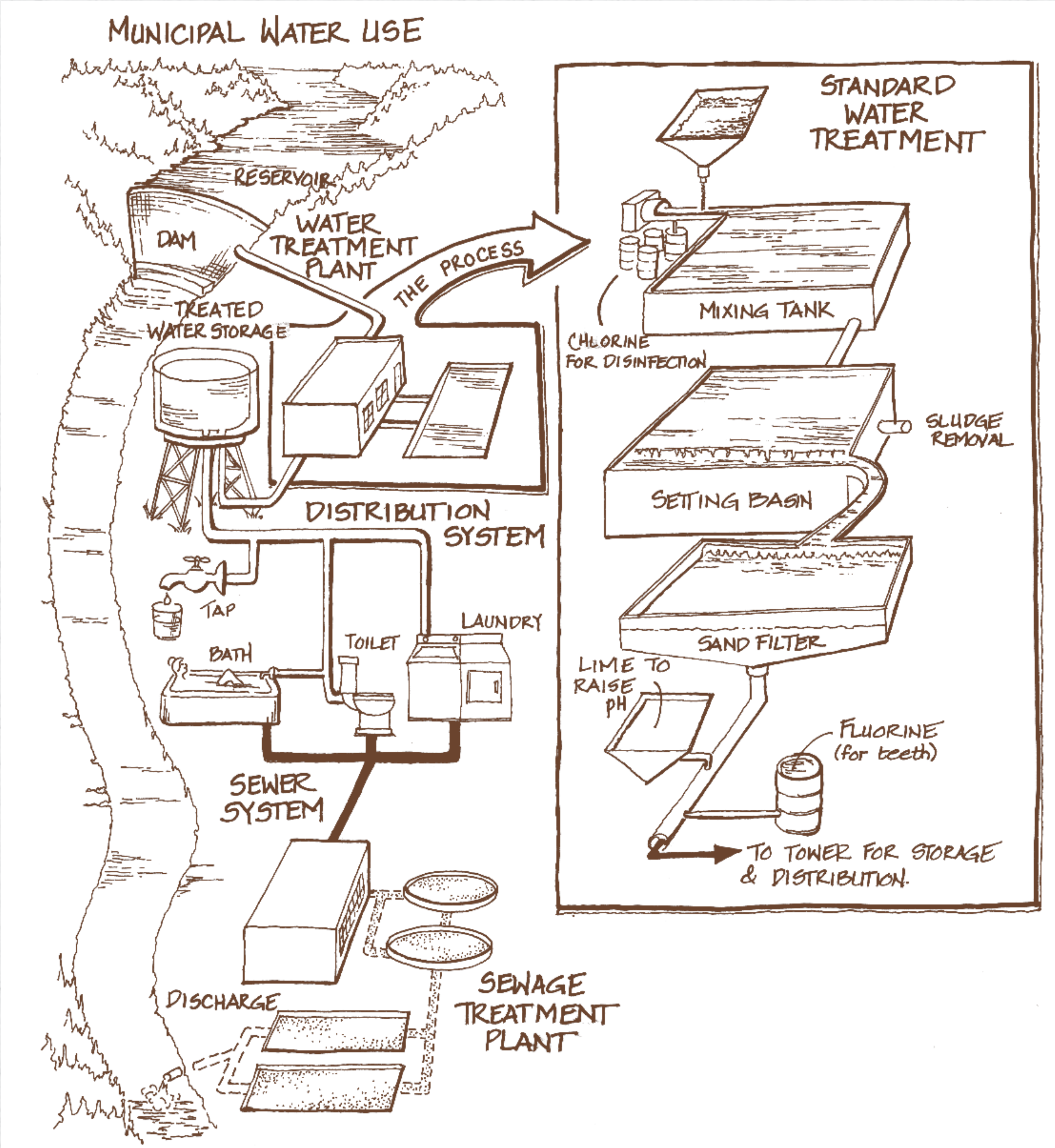
4. **CHLORINATION** – Chlorine gas is added to water to kill harmful bacteria and to remove manganese and iron from the water. Plant operators carefully monitor the amount of chlorine in the water.

5. **FILTRATION**– This process imitates the seepage of groundwater down through many meters of the Earth's layers, which filter out many contaminants before the water enters our aquifers. In a water treatment plant, water is filtered using layers of coal, sand, and gravel. Coal is used to remove odors, discoloration, and unwanted tastes. Sand filters remove any remaining particles and "floc." Gravel removes large particles and stabilizes the levels of sand and coal.

6. **FLUORIDATION** – This process does not clean the water, but it is the addition of hydrofluorosilicic acid (fluoride) to the water, which helps reduce human tooth decay.

7. **CORROSION CONTROL**– The natural pH of an undisturbed ecosystem is very close to 7, neutral. Over time, nature buffers very acidic or very alkaline conditions so that the pH returns to neutral. In a water treatment plant, water pH is checked and adjusted if necessary. If water is too acidic, it will corrode pipes, not only harming the pipes but also adding metal ions to the water.

8. **ADDITIONAL STEPS** – Sometimes water contains impurities that the filtering process does not remove, and additional procedures must be used. If immiscible liquids are present (liquids that will not mix with water, such as oil), the water is kept in one area until the oils float to the top. Dissolved substances such as electrically charged atoms or groups of atoms (ions) may also be a problem (e.g., calcium, magnesium, sodium, chloride, fluoride, phosphate, nitrate). De-ionizing chemicals can be added to water to remove these ions.



Water treatment in a watershed

Student Pages

Close to Home: Your Local Watershed Tables and Procedures

PROCEDURE

1. Log onto the EPA web site at http://cfpub.epa.gov/surf/locate/index.cfm.
2. Scroll down to "Locate by geographic unit." Select "zip code (5 digit number)," type in your local postal Zip Code and click "submit." Record in Table I: Local Watershed Information the 8-digit United States Geological Survey (USGS) Cataloging Code.

TABLE I: LOCAL WATERSHED INFORMATION (WASHINGTON, D.C. METRO AREA)

	Name of Watershed	USGS Cataloging Code
Home		
School		

3. Scroll down to "Citizen-based Groups at work in this watershed," and click the link. Choose five groups and fill out the information for each in table 2.

TABLE II: CITIZEN-BASED GROUPS AT WORK IN THIS WATERSHED

Group Name	Area Of Monitoring	# Of Volunteers	Website?

Close to Home: Your Local Watershed Tables and Procedures

4. **Scroll down to "Assessments of Watershed Health," and click on the link "Impaired Water for this Watershed." Choose a state (D.C., MD, or VA) and click the link. When the new page loads, scroll down and locate the chart titled "Causes of Impairment for Reporting Year 2010: Virginia, Middle Potomac-Anacostia-Occoquan." Choose five water bodies and list the cause of impairment for each in table 3.**

TABLE III: CAUSES OF IMPAIRMENT OF WATERSHED

Name Of Watershed	State Report	Water Body Name	Cause Of Impairment

5. **Further explore the cause of impairment by clicking on the box titled, "Frequent Questions," on the right-hand side of the screen. Scroll down to and click on "Assessing Water Quality (Questions and Answers)."**

Understanding Water Quality Index Procedure and Tables

PROCEDURE

1. **Your group will determine the WQI for two unknown water samples by conducting a test for each of the nine parameters. Each member of the team will become the "resident expert" for one or more of the parameters listed in Table II: Water Quality Parameters. You will perform these same nine tests to determine the WQI of a stream when you visit a national park. In the interest of time and efficiency, the nine tests should be divided into four subsets, with one group member completing each subset.**
   - Dissolved Oxygen and Biochemical Oxygen Demand (your teacher will supply water temperature for this test)
   - Turbidity and Total Dissolved Solids
   - Nitrates and pH
   - Orthophosphates and Fecal Coliform
   - Temperature change (your teacher will supply the values for this parameter)

2. **Decide who will research each set of parameters. Research your parameters by reading the resource information provided by your teacher. Prepare a report to present to your team after research iscompleted. Your report should include answers to the following:**

   a. What parameters are you researching?
   b. What is the importance of each parameter?
   c. What are the acceptable levels?
   d. What units are used to measure the parameter?

TABLE II: WATERSHED WATCHDOGS PARAMETERS FOR DETERMINING WQI

Parameter	Importance	Acceptable Levels	Units of Measure
Dissolved Oxygen			
Fecal Coliform			
pH			
BOD			
Temperature Change			
Orthophosphates			
Nitrates			
Turbidity			
Total Dissolved Solids			

Understanding Water Quality Index Procedure and Tables

3. Gather materials and test your two water samples. (Note: Your teacher will provide your team with two 5-day old water samples to test BOD, two prepared fecal coliform plates, and two temperature change values to use in determining the WQI.)

4. Record test results in Table III: Water Quality Index for Unknown Samples.

5. Determine the Q-value for your test results by using the Weighting Graphs beginning on page 43 of the Teacher Resources. Record your values on Table III.

6. On Table III, multiply your Q-value by the Weighting Factor. Record the product in the TOTAL block. (Note: The weighting factor indicates the importance of each parameter to the WQI. You will note onTable III that parameters have been ordered according to their weighting factor.)

7. Share your parameter report and your test results with team members. As other team members report, record their test results on Table III.

TABLE III: WATER QUALITY INDEX FOR UNKNOWN SAMPLES

	Unknown Sample 1 (Distilled Water)				Unknown Sample 2 (Pond, Stream, or Aquarium Water)			
Parameter	**Test Result**	**Q-Value**	**Weighting Factor**	**TOTAL**	**Test Result**	**Q-Value**	**Weighting Factor**	**TOTAL**
Dissolved Oxygen ________ mg/L Water Temp: ________° C		45	0.17			95	0.17	
Fecal Coliform		96	0.16			35	0.16	
pH		90	0.11			54	0.11	
BOD ________ mg/L of 5-day sample		98	0.11			11	0.11	
Temperature Change Water Temp: ____° C ____° C		92	0.10			73	0.10	
Orthophosphates		100	0.10			12	0.10	
Nitrates		97	0.10			27	0.10	
Turbidity		96	0.08			45	0.08	
Total Dissolved Solids		80	0.07			66	0.07	
	Overall WQI				**Overall WQI**			
	WQI Description				**WQI Description**			

Note: To calculate BOD, subtract DO in mg/L of the 5-day old sample from the DO in mg/L on the day the sample is taken.

Understanding Water Quality Index Procedure and Tables

8. **Calculate the Water Quality Index for each sample by adding the values in the TOTAL column.**

9. **Use the Water Quality Index Interpretation Scale to describe the water quality of each sample. Record the descriptions in Table III.**

10. **The resident expert will share with other group member's information about the acceptable levels for and importance of his or her parameter. In Table IV on page 15, place a check in the appropriate box indicating whether the level of each parameter is acceptable or unacceptable.**

WATER QUALITY INDEX INTERPRETATION

WQI	Description
100 - 90	Excellent
89 - 70	Good
69 - 50	Moderate
49 - 25	Bad
24 - 0	Very Bad

TABLE IV: EVALUATION OF TESTS RESULTS

	Sample 1		Sample 2	
Parameter	Within Acceptable Levels	Outside Acceptable Levels	Within Acceptable Levels	Outside Acceptable Levels
Dissolved Oxygen				
Fecal Coliform				
pH				
BOD				
Temperature Change				
Orthophosphates				
Nitrates				
Turbidity				
Total Dissolved Solids				

11. **Choose two parameters whose values fall outside acceptable levels. Assume that the samples came from a freshwater stream. Suggest possible reasons for the unacceptable levels.**

Datasheet for Data Analysis

Bridging the Watershed

Watershed Watchdogs 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)

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:

Datasheet for Data Analysis

Enter the data you collect using the chemistry kits in the fields below:

		You will perform this data analysis in the classroom		
Parameter	**Test Result**	**Q-Value**	**Weighing Factor**	**Total**
Dissolved Oxygen	____mg/L | Water Temp: ____˚C % sat.		0.17	
Turbidity	JTU		0.08	
Phosphates (Orthophosphates)	mg/L		0.10	
Nitrates	mg/L		0.10	
Change in Temperature	___˚C (above) - ___˚C (@ site) = Δ ˚ C		0.10	
Total Dissolved Solids	ppm		0.07	
pH			0.11	
Fecal Coliform	colonies/100 mL		0.16	
BOD	____mg/L | Water Temp: ____˚C % sat.		0.11	
		Overall Water Quality Index		
		WQI Description		

Water Quality Index (WQI) Description	
100-90	Excellent
89-70	Good
65-50	Moderate
49-25	Bad
24-0	Very Bad

Use digital meters to measure these parameters:

Stream Speed	ft/s

Parameter	**Test Result**
Dissolved Oxygen	% sat.
Conductivity (relates to Total Dissolved Solids)	µS/cm
pH	
Change in Temperature	___˚ C (above) - ___˚ C (@ site) = Δ ˚ C

Procedure and Tables for Data Analysis

1. The experts on BOD and fecal coliform will complete these tests. Enter these data on your data sheet.
2. Each person should copy the recorder's data on his/her own data sheet.
3. Determine the WQI by completing the Overall Water Quality Index of the Park Stream using the procedure described in "Understanding the Water Quality Index."
4. Record data from all the groups in Table V: Class Data for Water Quality Index of the Park Stream. Compute the class average for each parameter; then, determine the WQI based on the class average.

TABLE V: CLASS DATA FOR WATER QUALITY INDEX OF PARK STREAM

Parameter	Totals				Class Average
	Team 1	Team 2	Team 3	Team 4	
Dissolved Oxygen					
Fecal Coliform					
pH					
BOD					
Temperature Change					
Orthophosphates					
Nitrates					
Turbidity					
Total Dissolved Solids					
	Overall Average WQI				
	WQI Description				

5. Each group will use the class data to prepare a report. Begin your report by defining the study area and weather conditions using data from the group's data sheet.
6. Using Table V: Class Data for Water Quality Index of the Park Stream, summarize class data for the nine parameters. State the WQI value and its description to assess the health of the stream you studied.
7. Note individual parameter values that exceeded significant levels and propose possible reasons (e.g., errors in data gathering, weather conditions, land use affecting the study area).
8. The AFF website has additional resources to help you complete your report.
9. Complete the Evaluation Form: Performance List. 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 an average WQI for the group is accurately determined.			
2 All class data are entered, and an average WQI for the class is accurately determined.			
3 The summary report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data and WQI, a descriptive assessment of the health of the stream is included.			
5 Individual water quality parameters that exceeded significant levels are noted, and possible reasons are proposed.			
6 The summary report is clear, 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, 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:

Procedure for Polluted Water: Can We Clean It?

1. "Who Polluted the Potomac?" demonstrated the sources of some Potomac River pollutants. Think about methods you could use to clean this water.
2. Decide what needs to be done to clean the polluted water sample. Discuss your ideas with your team and agree on a cleaning procedure using any of the items from the materials list.
3. List the steps in your procedure and run your procedure.
4. Create a data table to record your observations of odor, color, clarity, and volume before and after each step. Your teacher should approve your procedures before you start the cleaning process.
5. After completing the process, answer the following questions:
6. How many milliliters of water did you lose in the cleaning procedure?
7. Calculate the percentage of water remaining at the end of your cleaning procedure.
8. Explain why it is important to know how much water is lost during water cleaning.
9. Is this water suitable for drinking? Why or why not?
10. If you had to repeat this procedure what would you do differently?
11. Compare the apparent color, odor, pH, orthophosphates, nitrates and turbidity reading for the three trials.
12. What "factor" do you think affected the apparent color, odor, pH, orthophosphates, nitrates and turbidity? Why?
13. What cleaning procedure do you think worked best for apparent color, odor, pH, orthophosphates, nitrates and turbidity? Why?
14. Could the cleaning procedure be adapted to clean water on a large scale?
15. Read "Imitating Nature to Clean Our Water" in the Resources to find out how pollutants are removed from municipal water. Discuss the article with your team members to help you determine how to remove undissolved solids, immiscible liquids, odors, and colors with minimal water loss.