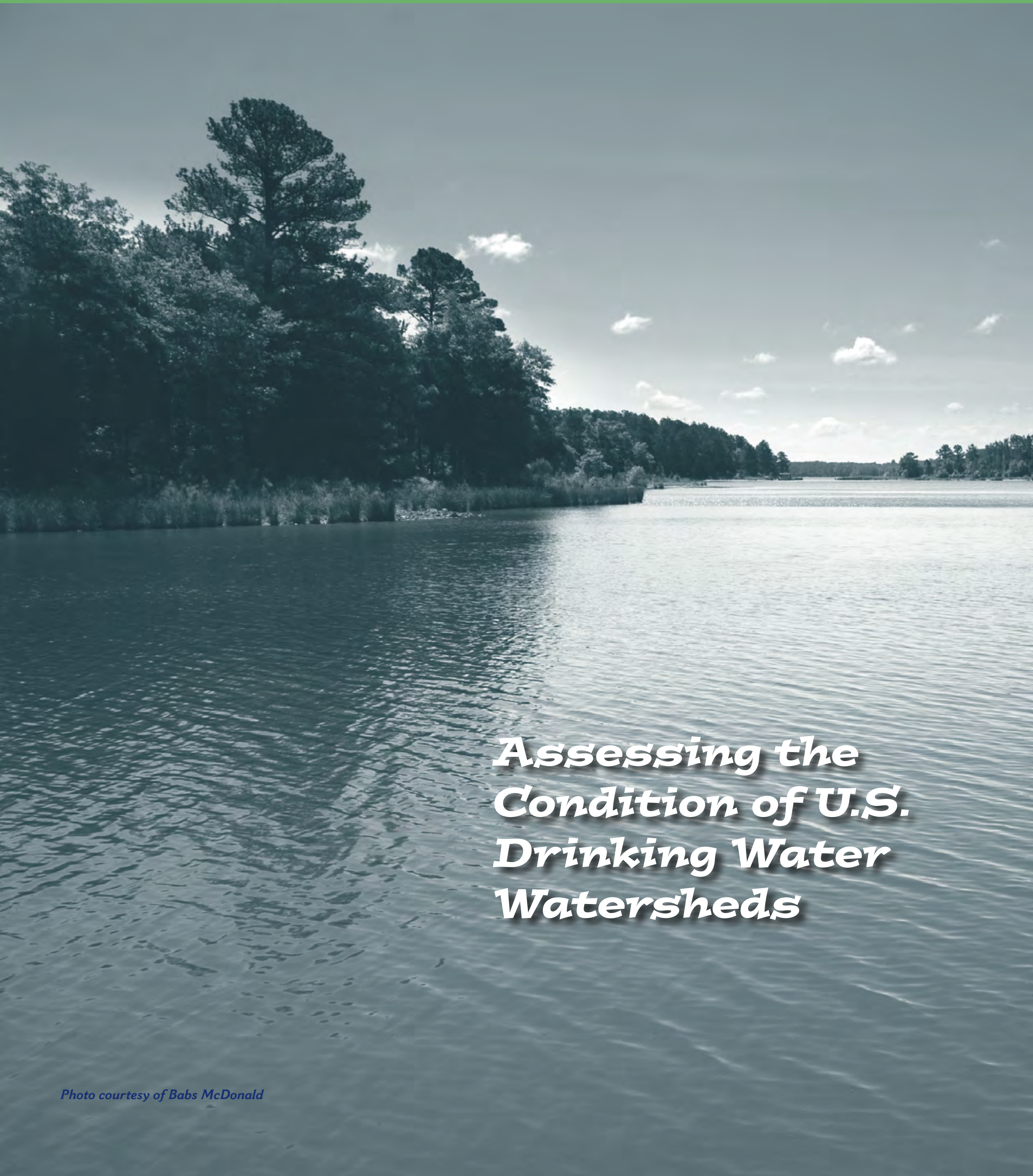
# Green Means Clean!

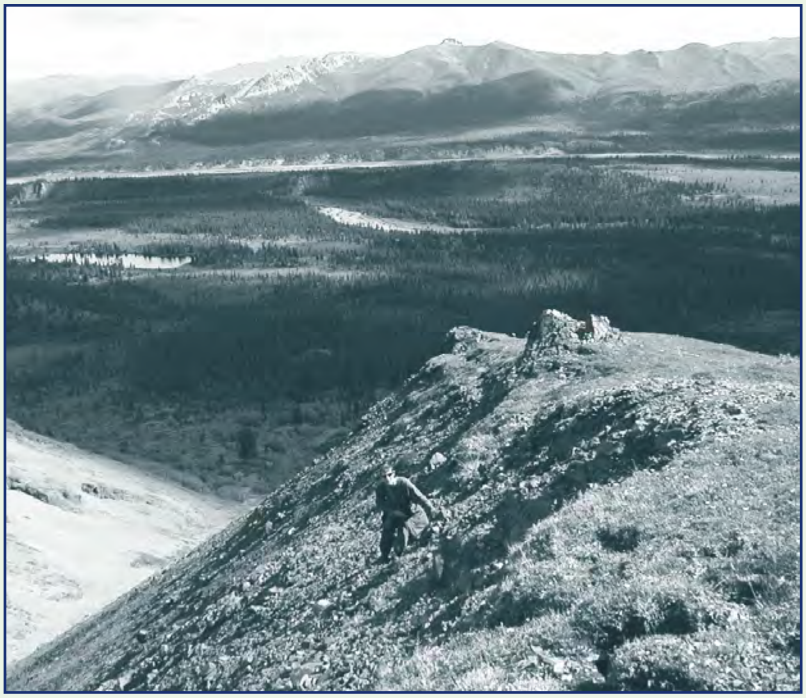


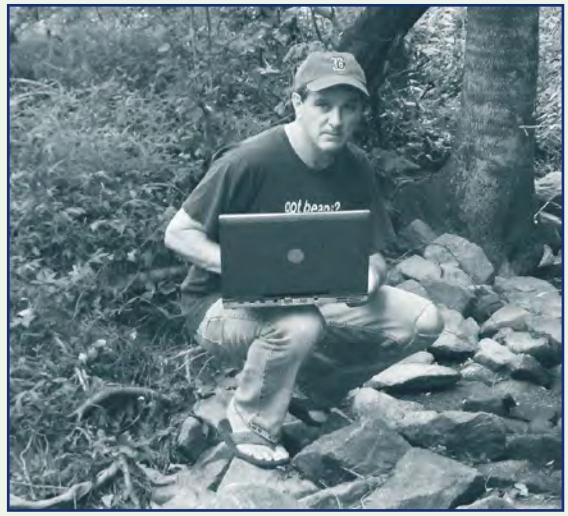
## Assessing the Condition of U.S. Drinking Water Watersheds

*Photo courtesy of Babs McDonald*

# Meet the Scientists

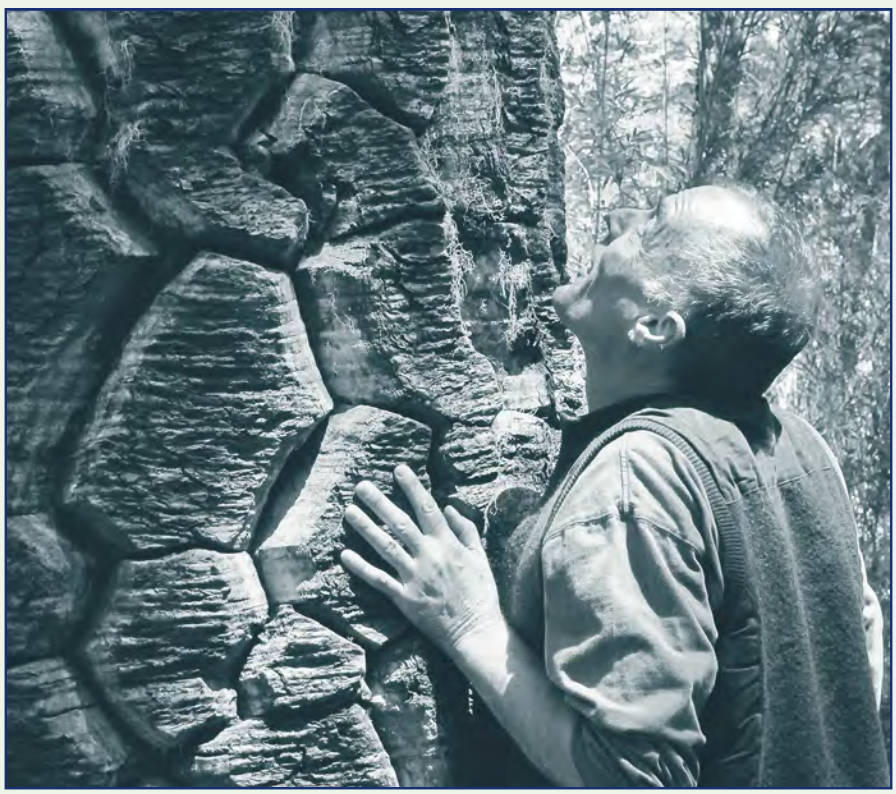
▶ **Dr. James Wickham**, Biologist: My favorite science experience is studying Earth's environment from space.





◀ **Mr. Timothy Wade**, Geographer: My favorite science experience is using Geographic Information Systems (GIS) to uncover environmental patterns that were not previously known.

▶ **Dr. Kurt Riitters**, Ecologist: My favorite science experience is asking and answering questions that have not been asked before.



Glossary words are **bold** and are defined on page 21.

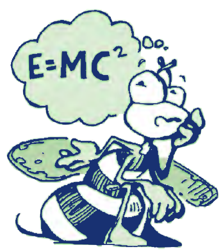
## What Kinds of Scientists Did This Research?

**biologist:** This scientist studies living organisms and living systems.

**ecologist:** This scientist studies the relationship of living things with each other and with the nonliving environment.

**geographer:** This scientist studies the relationship between Earth's natural environment and human society.

## Thinking About Science




Look at the section entitled, "What Kinds of Scientists Did This Research?" What do you notice about the kinds of scientists who are involved with this study? You probably noticed that three different kinds of scientists worked together to study drinking water watersheds in the United States. You might have also noticed that two of the scientists study relationships. When different kinds of scientists come together to conduct a study, each scientist brings a different perspective, a different kind of knowledge, and perhaps different scientific methods. These differences strengthen the study. One person may see or understand things that another person may not.

If you are holding a hard copy of *Natural Inquirer*, take a moment to look at the "What Kinds of Scientists Did This Research?" section of the other articles within the journal. You may also look at this section in more articles by viewing *Natural IQ*: *Southern United States Climate Change* edition at http://www.naturalinquirer.org. Notice that a variety of scientists came together to conduct the other studies. Relate this characteristic of scientific research to your own experiences. Share an experience of when having many different perspectives was an advantage for you.

## Thinking About the Environment

A watershed is an area of land where all the water that is underground within the area and all the water that drains off of its surface goes to the same place (**figure 1**).


**Figure 1**. What do you notice about watersheds? Illustration by Stephanie Pfeiffer.

Watersheds contain streams or rivers that carry surface water toward the oceans, and they may contain lakes or reservoirs (**re** zə **vwärz**) (**figures 2a and 2b**). Watersheds hold **groundwater**, which also flows into streams and rivers. In the United States, the largest watersheds are defined by the Continental Divide (**figure 3**). One of these large watersheds drains into the Pacific Ocean. The other large watershed drains into the Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea. Smaller watersheds are contained within each larger watershed in a nesting pattern (**figure 4**).

**Figure 2a**. Reservoirs are formed when a river is dammed. Reservoirs are built for many reasons, such as flood control or power generation. Photo courtesy of Babs McDonald.

**Figure 2b**. Many reservoirs are built to hold water that will be used as drinking water. Notice the drinking water treatment plant on this reservoir in northeast Georgia. For more information on water treatment plants, see page 16. Photo courtesy of Babs McDonald.

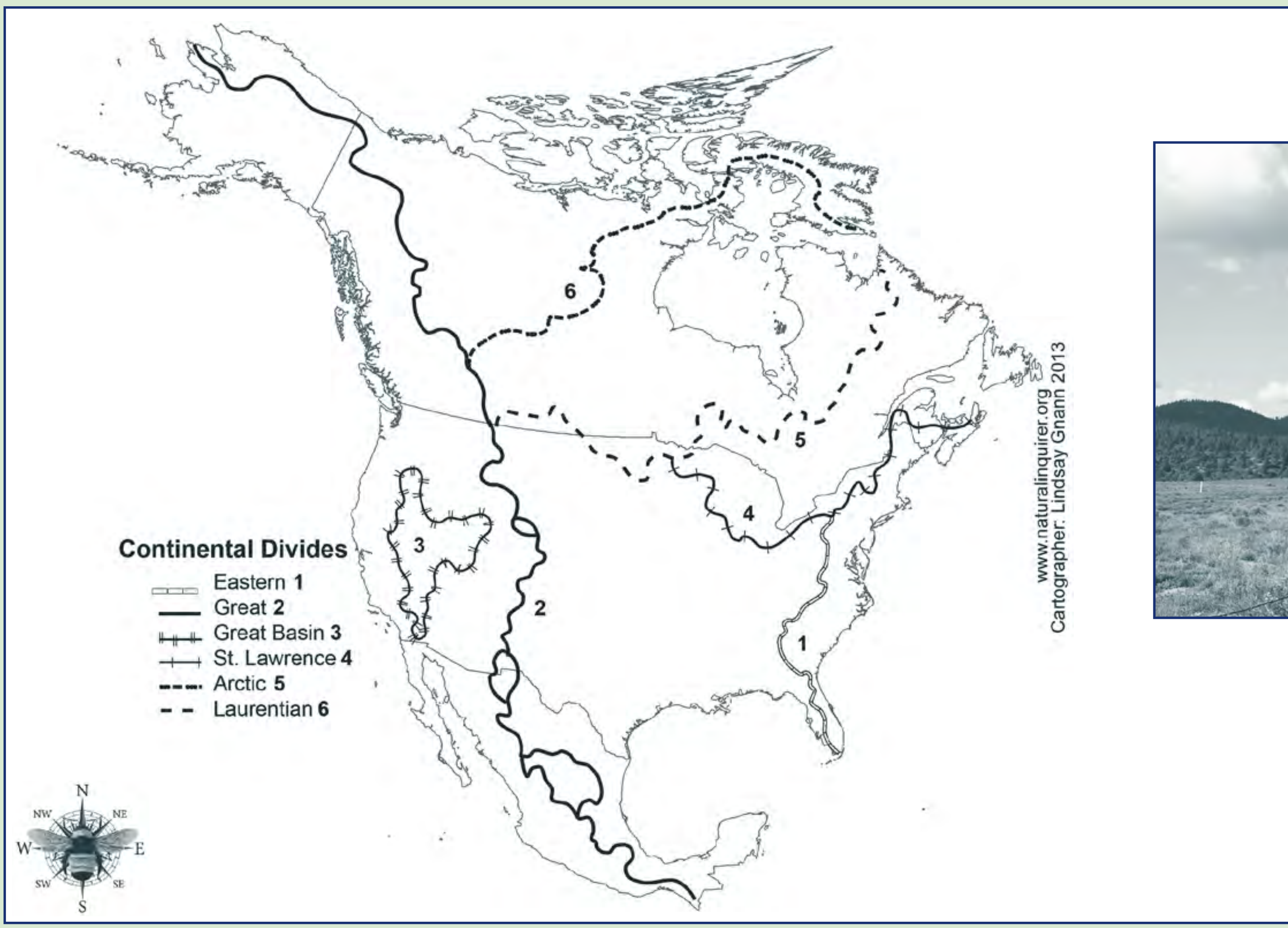


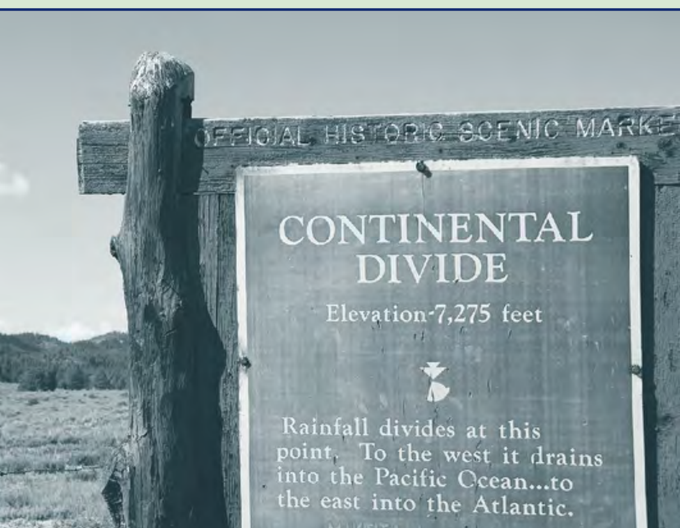

**Figure 3**. The Great Continental Divide defines two large U.S. watersheds. Notice the other large watersheds of North America. Identify which direction the water flows from the boundary of each watershed. Map by Lindsay Gnann and photo courtesy of Babs McDonald.


**Figure 4**. Smaller watersheds may be contained within larger watersheds. Illustration by Stephanie Pfeiffer.

# Introduction

Scientists estimate that 80 percent of all U.S. freshwater resources begin in forests. Approximately 60 million U.S. citizens rely directly on national forests for their water. About two-thirds of the U.S. population use drinking water from surface sources. Surface sources of drinking water include streams, rivers, lakes, and reservoirs (**figure 5**). People who manage drinking water sources have recognized the relationship between **conservation** of natural land and improved drinking water quality. When land is covered with vegetation, surface water is cleaner. Cleaner water means lower water treatment costs and safer drinking water.

Managers take a number of actions to protect drinking water. Starting in 1974, with the passage of the Safe Drinking Water Act, managers focused on detecting sources of water pollution. By 1996, people had begun to think differently about how to provide clean



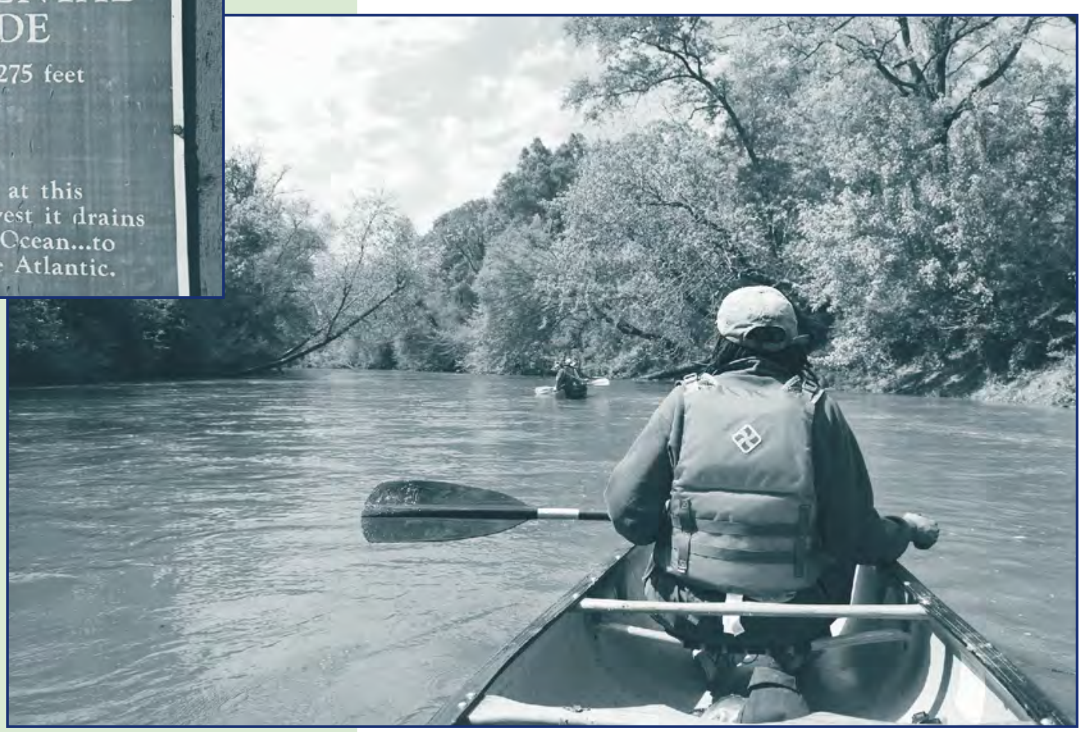



**Figure 5**. Rivers, as well as lakes and reservoirs, are surface sources of drinking water. Photo courtesy of Babs McDonald.

drinking water. People realized that protecting surface source water was more effective and **efficient** than just detecting pollution. In 1996, **amendments** to the Safe Drinking Water Act shifted the focus from detection of pollution to protection of source water. A big part of protection is managing drinking water watersheds so that the surface water is clean. This kind of management means that the land is purposely managed to protect surface sources of drinking water.

The 1996 Safe Drinking Water Act amendments also required each State to assess the condition of its source water. These assessments are important, as they alert managers to the condition of drinking water watersheds. If a watershed's natural condition becomes **degraded** or the land is developed for other uses, for example, managers can address the problem to protect water quality. Unfortunately, State-by-State assessments do not provide a regional or national understanding of drinking water watersheds. Each State might do its assessment a little differently. Watersheds often cross State boundaries, and watersheds are managed across State boundaries (**figure 6**). The scientists in this study, therefore, were interested in conducting a national assessment of drinking water watersheds that crossed State boundaries.

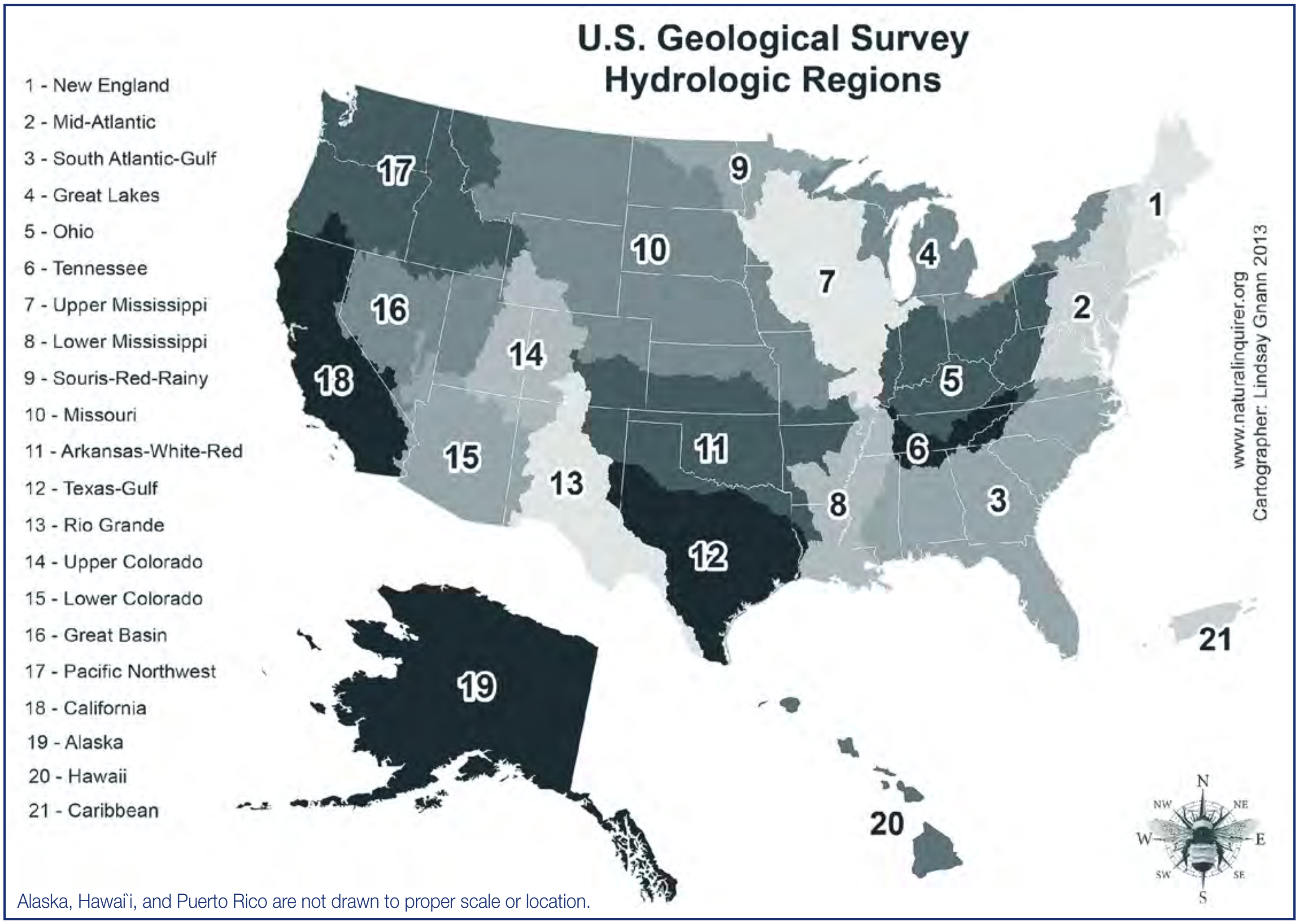



**Figure 6**. The U.S. Geological Survey divides the United States into 21 **hydrologic** regions. These regions contain either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region. In which hydrologic region do you live? Map by Lindsay Gnann.

# What Is the Safe Drinking Water Act?

Congress passed the Safe Drinking Water Act in 1974 to protect public health by **regulating** the Nation's public drinking water supply. The law was amended in 1986 and 1996 and requires actions to protect drinking water and its sources. These sources include streams, rivers, lakes, reservoirs, springs, and groundwater wells. Springs and groundwater wells are belowground sources of drinking water. In this study, the scientists were interested in surface drinking water sources.

The Safe Drinking Water Act identifies risks to safe drinking water. These risks include, for example, **pesticide** application, mining, and landfills (**figure 7a**). The act also identifies the many ways drinking water can be protected. These protective actions create barriers to water pollution (**figure 7b**). Examples of barriers to water pollution include sustainable land management and public education programs.


**Figure 7a**. The Safe Drinking Water Act identifies risks to safe drinking water. Illustration by Stephanie Pfeiffer, adapted from the Safe Drinking Water—Protecting America's Public Health Poster (EPA 816-H-02-001 January 2002).

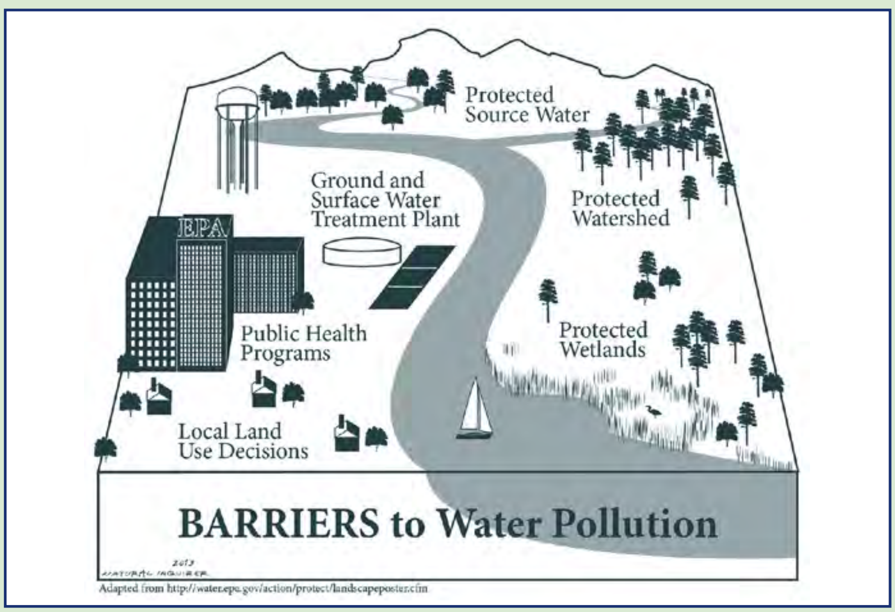



**Figure 7b**. The Safe Drinking Water Act identifies barriers to water pollution. These barriers are protective actions that directly and **indirectly** protect water quality. Illustration by Stephanie Pfeiffer, adapted from the Safe Drinking Water—Protecting America's Public Health Poster (EPA 816-H-02-001 January 2002).

## Reflection Section

- Do you know where your drinking water comes from? If so, what is the source? If you are not sure of the source of your drinking water, do some research to identify the source. Your source might be a stream, river, lake, or reservoir. You may also have a spring, an individual water well at your home, or a community well.
- Look at figure 7a. Why do you think **wastewater** treatment plants are identified as a risk to safe drinking water?
- Explain in your own words why the scientists wanted to conduct a national assessment of drinking water watersheds.

## Methods

First, the scientists located all surface drinking water intakes. A surface drinking water intake is a pipe in lakes, streams, rivers, or reservoirs that takes water from the source and carries it to a water treatment plant (**figures 8, 9a, 9b, and 9c**). The scientists found 5,265 of these intakes across the United States.

The scientists then used maps to trace backwards from the water intakes. Tracing backwards from the intakes enabled scientists to identify the watershed for each intake. Each watershed included all the land area supplying water to the intake. Then, the scientists identified in which of the 21 hydrologic regions of the United States each watershed belonged (see figure 6).

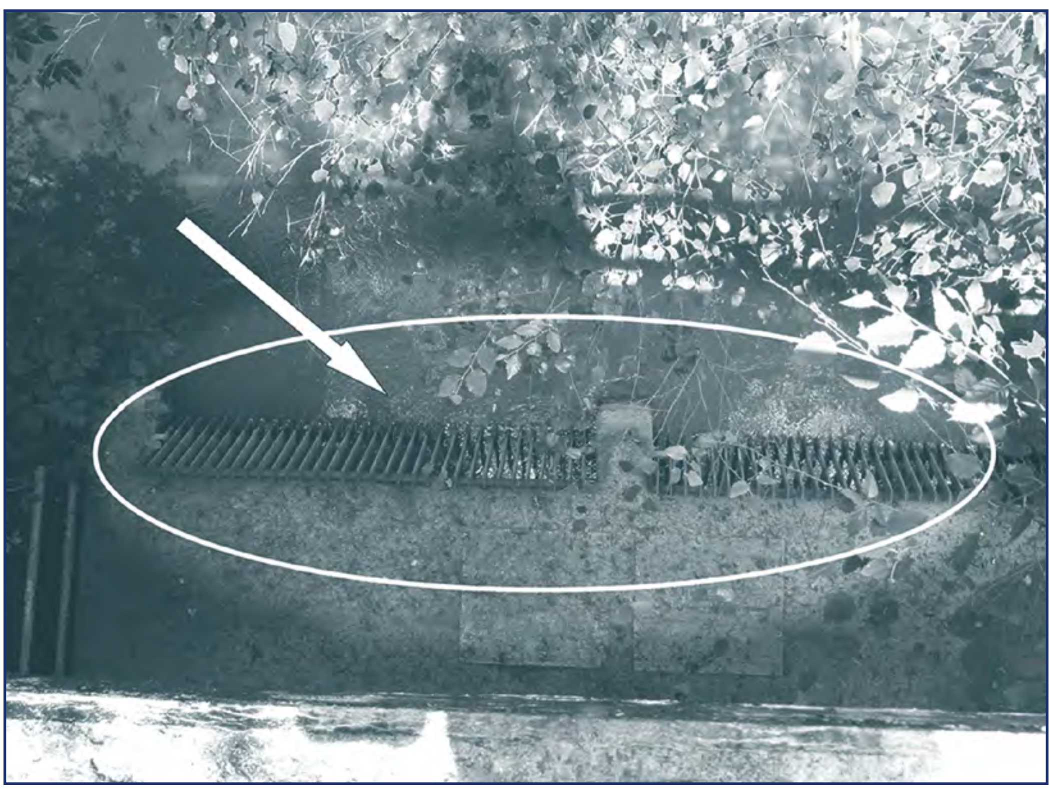


**Figure 8**. Water enters a water treatment system through drinking water intakes. In this photo, water enters through a grate at a river's edge and into a pipe for transport to the water treatment plant. This photo was taken from above the water intake. Photo courtesy of Babs McDonald.


**Figures 9a, 9b, and 9c**. Water treatment plants clean the water received from watersheds and water intakes. Photos courtesy of Babs McDonald.

# How Is Water Treated So That It Becomes Clean Enough To Safely Drink?

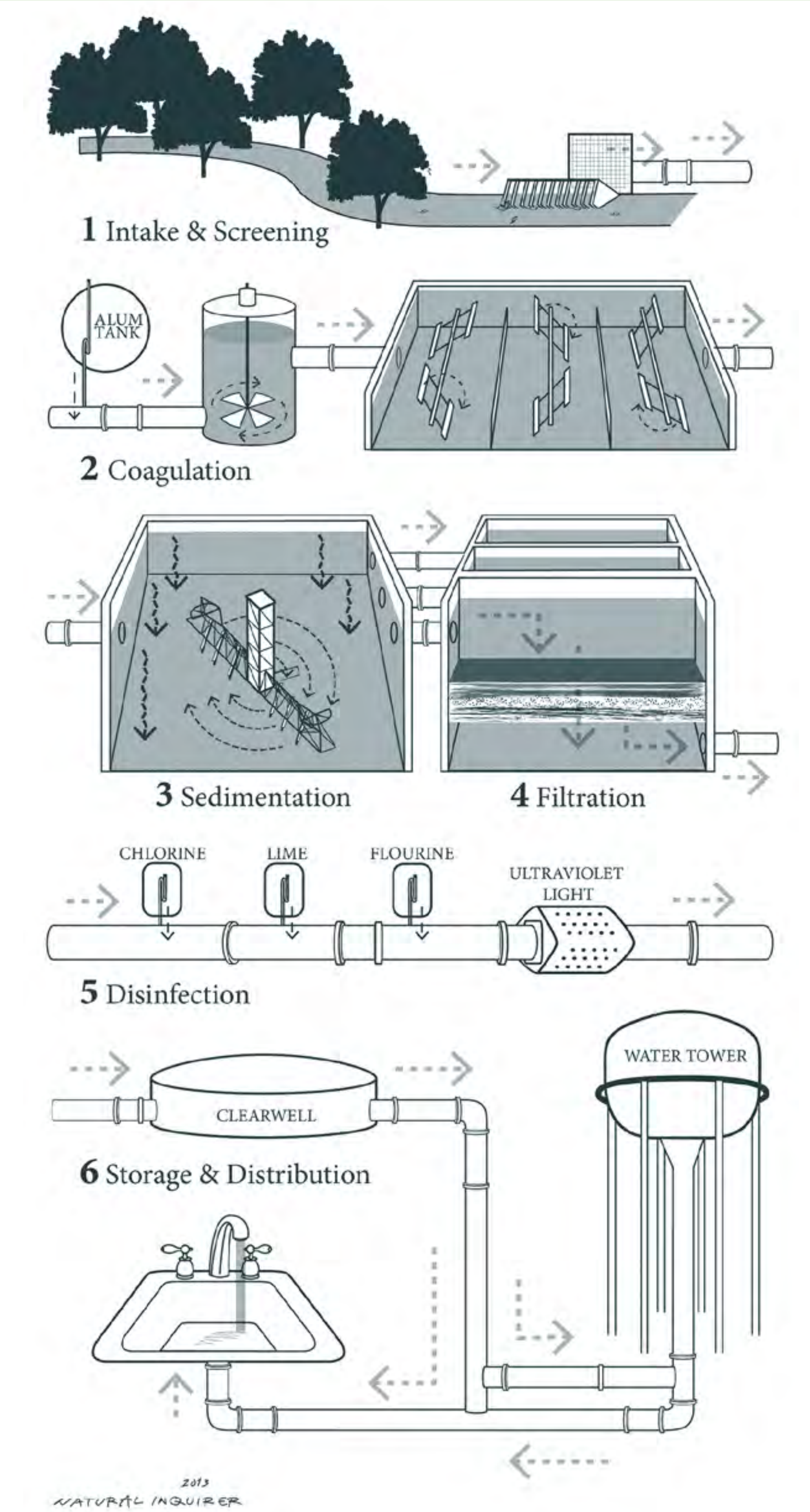



**Figure 10**. Water entering a drinking water treatment system is treated using a number of steps. Illustration by Stephanie Pfeiffer.

Water entering a drinking water treatment system is treated using a number of steps (**figure 10**). When water is taken from a river (and before it reaches the water treatment plant), the water is filtered through screens to remove sticks and leaves. Water taken from a reservoir does not usually need to be screened. When water reaches the plant, coagulation is often the first step in treatment. Chemicals with a positive electrical charge are added to the water. The positive charge of these chemicals neutralizes the negative charge of dirt and other dissolved particles in the water. When this process occurs, the particles bind with the chemicals and form larger particles, called floc.

Due to its weight, floc settles to the bottom of the water supply. This settling process is called sedimentation.

After the floc has settled to the bottom of the water supply, the clear water on top passes through a filtration process. Filtration uses materials such as sand, gravel, and charcoal to filter the water. Filtration removes dissolved particles, such as dust, parasites, bacteria, viruses, and chemicals.

After the water is filtered, a disinfectant (such as chlorine) is usually added to kill any remaining parasites, bacteria, and viruses. Disinfectant also protects the water from germs when it is piped to homes and businesses.

Water is stored at the water treatment plant in a clearwell before being piped to homes and businesses. Some of the water is piped to and stored in water towers located throughout the community. Most of the water is piped directly to homes and businesses (**figure 11**). Water travels through these pipes and into a building's plumbing system.

**Figure 11**. Water pipes are laid underground near roads. These pipes bring clean water from the water treatment plant to homes and businesses, including your home and school. The next time you turn on a faucet, think about the journey each drop of water has taken from its surface water source to your faucet. Photo courtesy of Babs McDonald.

The scientists needed more information to do their analysis. The scientists used information from an existing national database on land cover. This database is made up of satellite photographs taken of Earth's surface (**figures 12 and 13**). Land cover is the physical cover at Earth's surface. Examples of land cover include forest, grass, asphalt, water, and buildings. Some of these land covers are classified as urban, such as buildings. Some of these land covers are classified as natural, such as forests.

**Figure 12**. Landsat satellites take images of Earth's surface. The photographs are used for many purposes. Photo courtesy of National Aeronautics and Space Administration.

Using this database of photographs, the scientists noted changes between 1992 and 2001 in land cover for areas identified as urban, natural, agricultural, and water.

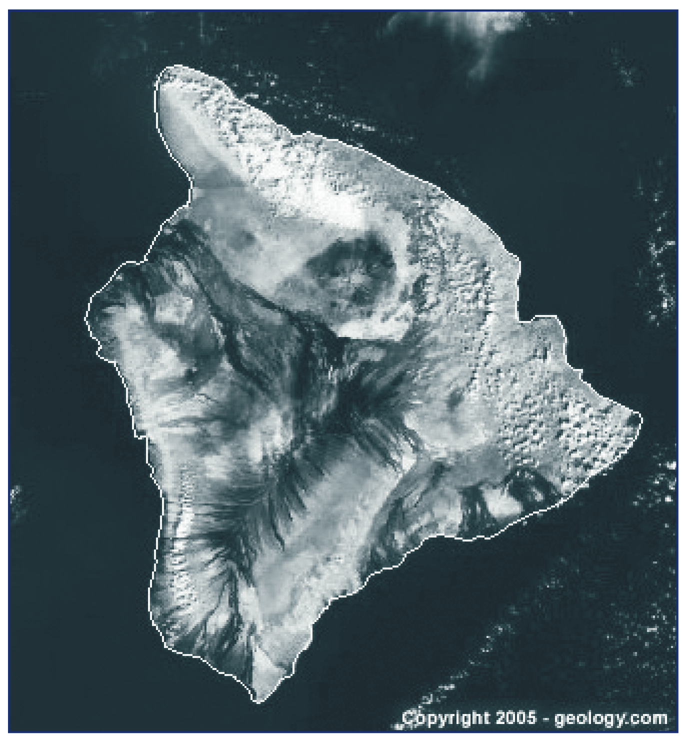



**Figure 13**. Landsat images are commonly used today. Landsat images help us understand how Earth's surface is changing over time. This Landsat image is of the Island of Hawai`i. Image courtesy of http://www.geology.com.

They identified, for example, whether the amount of urban land expanded or got smaller between 1992 and 2001 for each of the drinking water watersheds.

Next, the scientists looked at another database called the Protected Areas Database of the United States. This database identifies land that is protected from development. Development is what happens when land is converted from natural to urban or agricultural uses. The Protected Areas Database identifies public land and conservation land. The scientists figured out how much land in each of the drinking water watersheds was protected. Land that is protected is less likely to be developed into roads and buildings, or used for agriculture.

Finally, the scientists put all of this information together into a computer. For each of the drinking water watersheds, the scientists figured out how much of the land was urban, natural, agricultural, or covered in water. They figured out percentages for 1992 and 2001. By looking at data for 1992 and 2001, the scientists figured out if each watershed was becoming more urban, more agricultural, more natural, or had not changed. Then, the scientists calculated the percentage of land in each watershed that was protected from further urban and agricultural growth.

## Reflection Section

- Explain what kind of information the scientists compared for each of the drinking water watersheds.
- What is the relationship between land cover change and drinking water quality?

## Findings

Most major U.S. rivers are used to supply drinking water to Americans. The scientists discovered that about two-thirds of surface drinking water intakes are in rivers. One-third of the intakes are in lakes and reservoirs. Nationwide, most of the land in drinking water watersheds is covered with plants and trees. The scientists found that the **median** watershed percentage of natural land cover nationwide was 77.1 percent (**table 1**).

| Land Cover | Median Percentage |
|---|---|
| Natural | 77.1 |
| Agricultural | 8.1 |
| Urban | 5.2 |

**Table 1**. Comparison of the median amount of land characterized as natural, agricultural, and urban in U.S. drinking water watersheds.

## Number Crunch

- What is the total percentage of drinking water watershed land accounted for in table 1? What could be one reason these numbers do not add up to 100 percent?

The scientists also discovered that about 3 percent of the land in U.S. drinking water watersheds was protected from development. The Western United States, however, has a higher percentage of protected land in drinking water watersheds. This higher percentage is due to the large amount of public land in the Western United States (**figure 14**). Public land is generally kept in a natural condition with limited development.

Between 1992 and 2001, land cover changed in some of the drinking water watersheds.

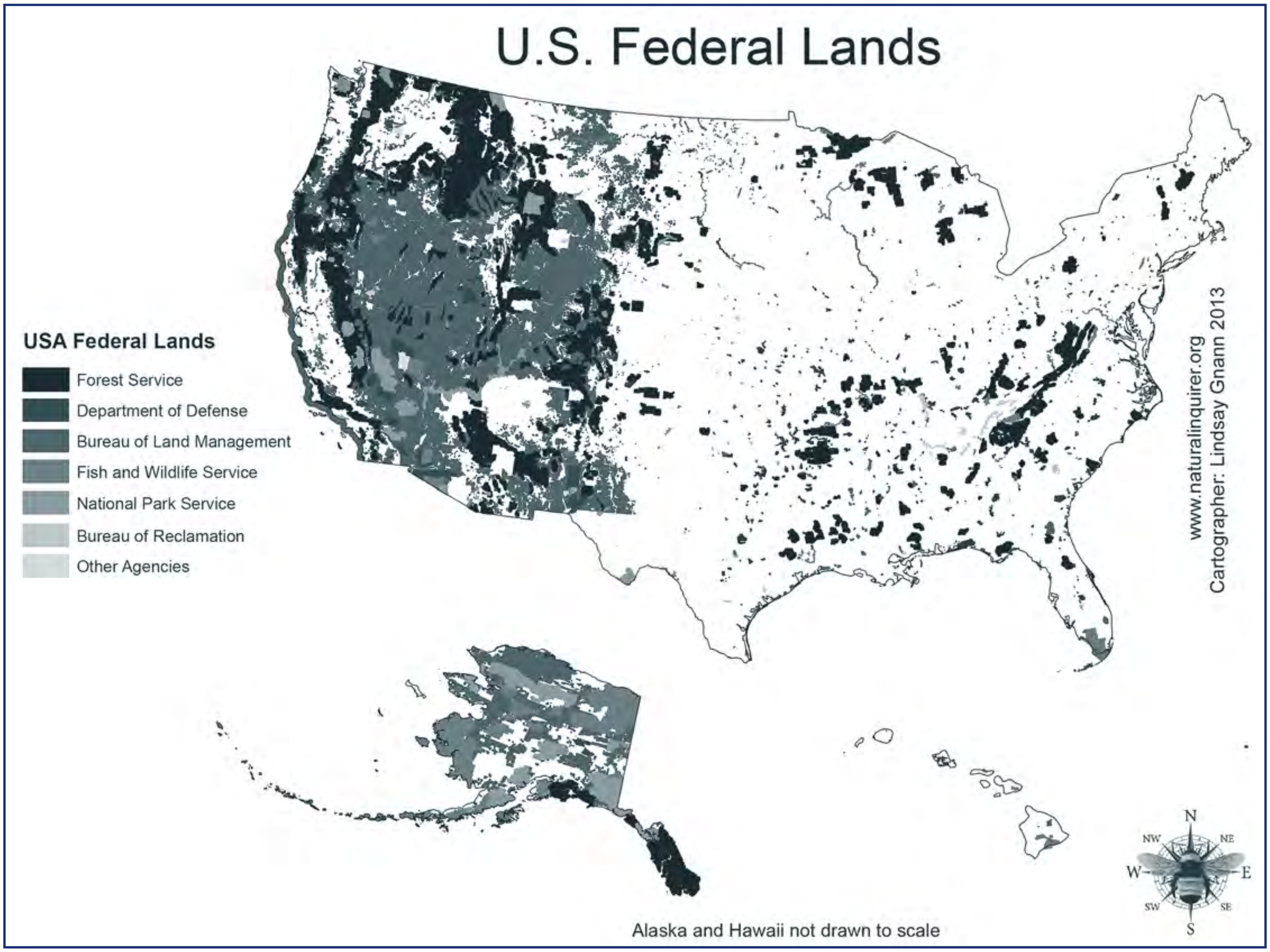



**Figure 14**. Observe the difference in the amount of western public land as compared with the amount of eastern public land. What do you notice? Map by Lindsay Gnann.

About 23 percent of the watersheds lost at least 1 percent of their natural vegetation. About 5 percent of the watersheds gained at least 1 percent in natural vegetation. In the Southeast and Ohio hydrologic regions (see figure 6), 42 percent of the watersheds lost at least 1 percent of their natural vegetation.

About 9 percent of the drinking water watersheds had at least a 1-percent increase in urban land between 1992 and 2001. Most of this increase was in the Eastern United States. Three-fourths of all watersheds nationwide, however, increased in urban land by some percentage between 1992 and 2001.

## Number Crunch

- Consider a watershed with a 1-percent increase in urban land. This watershed contains 30,000 hectares. To find out how many acres are in this watershed, multiply 30,000 times 2.471. Following a 1-percent increase in urban land, how many more hectares (and acres) are now in urban land? Is a 1-percent increase of land a large amount of land? Why or why not?

## Reflection Section

- What national trends in land cover change were discovered for the drinking water watersheds?
- Based on what you learned in this article, would you say that future threats to drinking water quality are equal across the United States? Why or why not? Provide reasons for your answer.

## Did You Know?

The average U.S. household uses about 94,000 gallons of water each year. That amount is about 257 gallons used per household each day, or about 11 gallons each hour. In 2010, the U.S. Census Bureau estimated that an average U.S. household has 2.58 people. Based on this information, do you think your household uses more or less than 94,000 gallons of water every year?

## Discussion

The scientists found that drinking water watersheds are mostly covered with natural vegetation. In some areas of the United States, however, watersheds contain a high percentage of urban land. Twenty percent of the Nation's drinking water watersheds have less than 50 percent natural vegetation. In addition, 8 percent of the Nation's drinking water watersheds contain at least 20 percent urban land. Over time, drinking water watersheds are losing natural vegetation and are becoming more urbanized. These trends indicate that many surface sources of drinking water may become more exposed to pollutants.

This study shows the importance of taking a regional and national look at U.S. drinking water supply. U.S. population increases will put more land use demands on drinking water watersheds. As more land becomes urbanized, drinking water source protection will likely become more difficult unless the percentage of protected lands increases as well.

## Reflection Section

- The scientists discovered that 8 percent of the Nation's drinking water watersheds contain at least 20 percent urban land. Do you think these more urbanized watersheds are mostly found in the Eastern United States or the Western United States? Why?
- Based on this article, do you think that drinking water sources will face more challenges from pollution in the future? Why?

Adapted from Wickham, J.D.; Wade, T.G.; Riitters, K.H. 2011. An environmental assessment of United States drinking water watersheds. Landscape Ecology. 26: 605–616. http://www.srs.fs.usda.gov/pubs/ja/2011/ja_2011_wickham_001.pdf.

# Glossary

**amendment** (ə **men(d)** mənt): A change in wording or meaning especially in a law, bill, or motion.

**conservation** (**kän(t)** sər **vā** shən): The care and protection of natural resources such as forests and water.

**database** (**dā** tə bās): A collection of related data organized for convenient access, generally in a computer.

**degrade** (di **grād**): To make the quality of something worse.

**efficient** (i **fi** shənt): Bringing about the result wanted with the least amount of time, waste, or materials.

**groundwater** (**grau̇nd wä** tər): Water that sinks into the soil and is stored in aquifers.

**hydrologic** (**hī** drä **lə** jik): Relating to the properties, distribution, and circulation of water on and below Earth's surface and in the atmosphere.

**indirect** (in dī **rekt**): (1) Not straightforward and open; (2) Not directly aimed at.

**median** (**mē** dē ən): A value in an ordered set of values below and above which is an equal number of values or which is the arithmetic mean of the two middle whole values if there is not one middle whole number.

**pesticide** (**pes** tə sīd): A substance that is used to kill animals or insects that damage plants or crops.

**regulate** (**re** gyə lāt): (1) To control according to a system; (2) To bring under control of law or some authority.

**wastewater** (**wāst** wä tər): (1) Water that has been used; (2) Sewage.

Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com. Definitions are limited to the word's meaning in the article.

How does this scene relate to this article?

## FACTivity

### Time Needed

One class period

Common Core Connection

### Materials

(for each student or group of students)

- Three paint roller pans
- One shovel
- 3/4 cup liquid kitchen oil, such as canola oil
- 2 gallons of water in plastic jugs
- One garden sprinkler can
- Blue or red food coloring

The questions you will answer in this FACTivity are: Which land cover surface best protects water quality and why?

### Methods

Identify an area of thick grass near the edge of a grassy area. Ask an adult if the area you have chosen is a good location. Using the shovel, dig up an area of grass the size of one-half of the paint roller pan, including ½ to 1 inch of the soil underneath. Brush off the loose soil and place the grass into one of the paint roller pans. The roots of the grass should be holding the soil together. Make sure that the area of grass that you remove is away from the main lawn area.

Identify an area of bare soil. Bare soil is dirt with little or no vegetation. Dig up a shovelful of bare soil and place it into the second paint roller pan, to about 1-inch deep. If it is not possible to find the grass or bare soil in your schoolyard, your teacher will bring them to class. Leave the third paint roller pan empty. Line up the three paint pans so that you can easily compare them (**figure 15**).

During your experiment, use the graphic organizer in the next section to answer the following questions. What do think each of the paint pans represents? (Hint: Think about the different land covers studied in the research you just read.) What do the water and oil represent? (The answers are given after the graphic organizer.) Based on your reading of this article, what do you predict will happen when oil is added and water is poured across each of the paint roller pans? Write your prediction in the form of a complete sentence in the graphic organizer.

Pour 1/4 cup of oil over the contents of each pan. Wait 5 minutes.

Add food coloring to the water. Mix the water and food coloring together until it makes a bright color. Add the water to the garden sprinkler can. Using the sprinkler can, pour an equal amount of water over each of the three paint pans. As the water drains into the bottom of each pan, observe the drained water in each of the pans. What differences do you see between the water in each pan? What has happened to the water in each case? What do you think is the reason for the water's appearance in each of the pans?

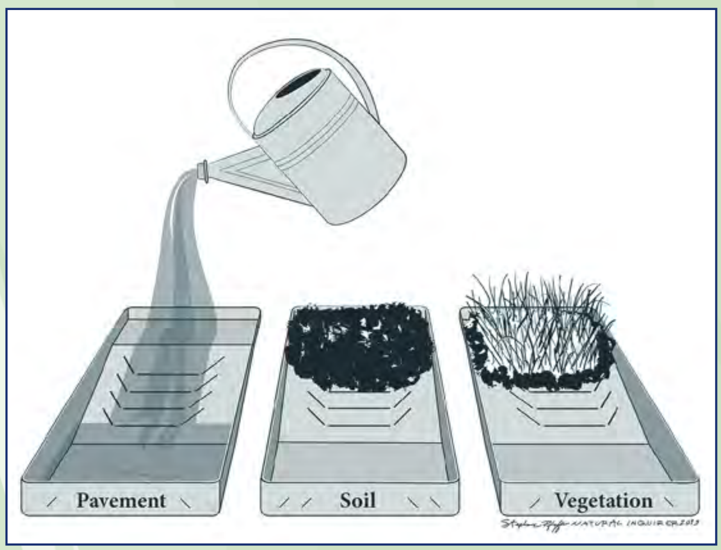



**Figure 15**. How to set up the paint roller pans. Illustration by Stephanie Pfeiffer.

# Graphic Organizer

Note: Write using complete sentences, proper grammar, and appropriate punctuation.

| | |
|---|---|
| The grass represents: | |
| The soil represents: | |
| The bare aluminum represents: | |
| Write your predictions about how the water will look after oil is added and the water drains into each pan. | Bare aluminum:<br><br>Grass:<br><br>Soil: |
| Describe your observations of the water in each pan. | Bare aluminum:<br><br>Grass:<br><br>Soil: |
| Explain why you think the water looks like it does in each pan. | Bare aluminum:<br><br>Grass:<br><br>Soil: |
| How does this experiment relate to the research you read about in the article? | |
| Based on what you learned, what are your conclusions about land cover and water quality? | |

In this FACTivity, each paint roller pan represents a different watershed land cover. The grass represents a watershed with vegetation. The soil represents a watershed with agricultural land. The bare aluminum represents an urban watershed with pavement, such as roads and parking lots. The oil represents pollution coming from cars, industry, and agriculture. The water represents rain.

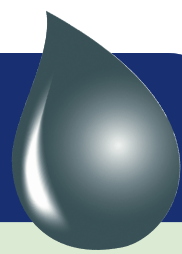
Now answer the question posed at the beginning of this FACTivity: Which land cover surface best protects water quality and why? Share your answer with your class.

## *FACTivity Extension*

To better understand how water treatment plants clean water, do the U.S. Environmental Protection Agency water filtration activity found at http://www.epa.gov/ogwdw/kids/flash/flash_filtration.html.

If you are a trained Project Learning Tree educator, you may use "Water Wonders" as an additional resource.

## *Safe Drinking Water Hotline*



The Safe Drinking Water Hotline provides information about drinking water and groundwater programs authorized under the Safe Drinking Water Act.

800–426–4791

http://water.epa.gov/drink/hotline/

## *Web Resources*

U.S. Environmental Protection Agency: Learn About Water
http://www2.epa.gov/learn-issues/learn-about-water

U.S. Environmental Protection Agency: Surf Your Watershed
http://cfpub.epa.gov/surf/locate/index.cfm

U.S. Environmental Protection Agency Video: After the storm: The impact of storm water runoff on drinking water supply
http://water.epa.gov/action/weatherchannel/index.cfm

U.S. Environmental Protection Agency Water: Educator Resources
http://water.epa.gov/learn/resources/nationswaters_index.cfm

U.S. Environmental Protection Agency Water: Educator Resources: What Can I Do?
http://water.epa.gov/learn/resources/projects.cfm#projects