Section Preview of the Student Book for

EDC Earth Science

Chapter 2 (through Activity 2)

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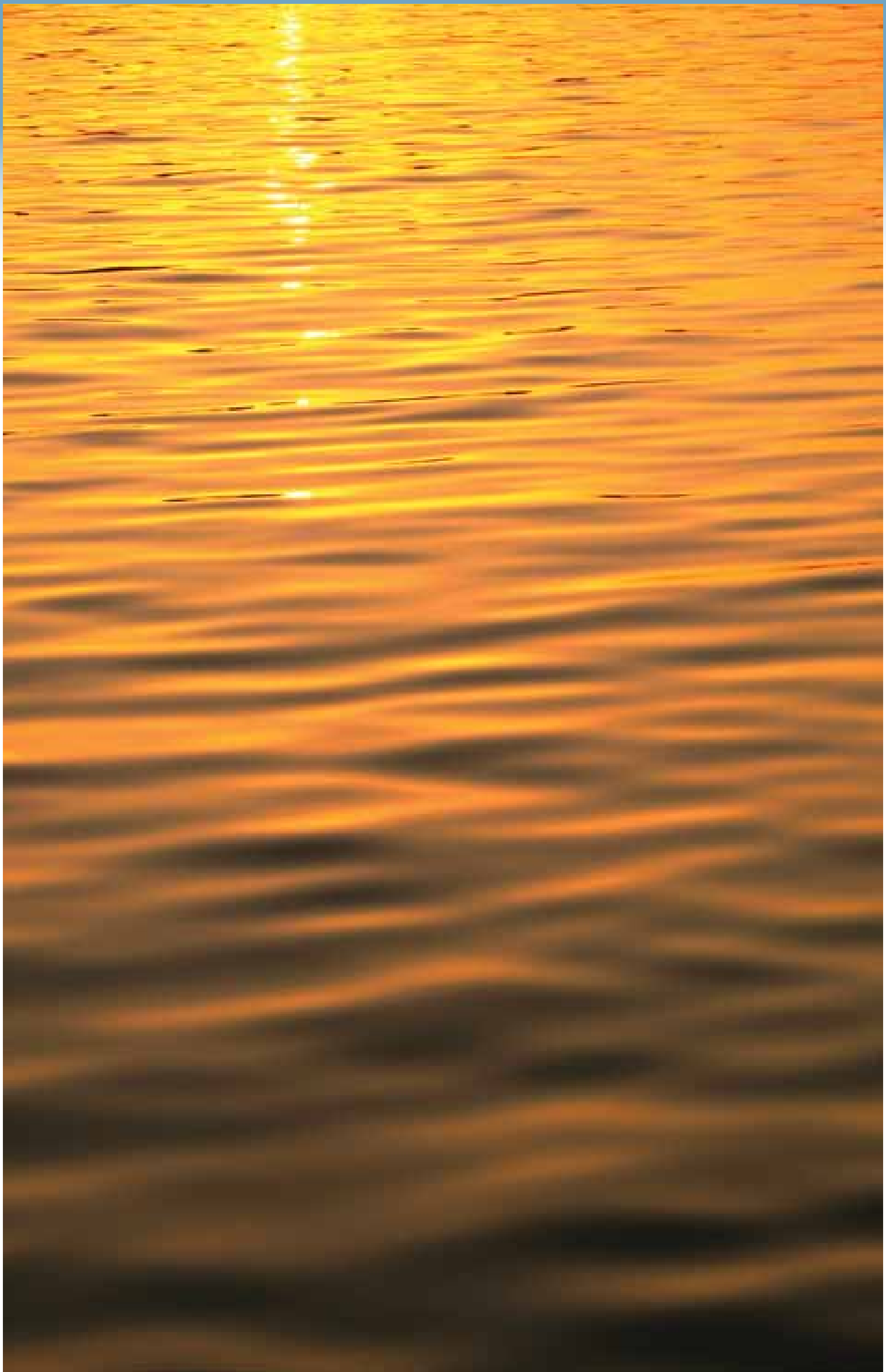
UNIT 1

Hydrosphere: Water in Earth's Systems



CHAPTER TWO

Life's Blood: Seeking Water from Earth

Water is personal. It makes up 50%–70% of your body and makes life possible. No one can doubt that water is a vital resource, but is there any reason to worry about it? After all, you seem to live in a water-saturated world. Water is in the rain, clouds, streams, rivers, and lakes around you. In fact, the water of the oceans covers 70% of Earth's surface!

It may seem strange, but some experts say that in the future wars will be fought over water. There are places around the world where water has been scarce for some time. Consider the following facts, from the book *Water Wars*, written in 2003 by Diane Raines Ward:

- *In Sydney, Australia, water theft, which can be reported on a twenty-four-hour hotline, carries a fine of $20,000.*
- *Water-short California produces about half of the United States' fruits and vegetables and much of its dairy products.*
- *North Dakota had to pay for a study to prove that it wasn't poaching Montana's clouds.*
- *At El Tofo, University of Chile, researchers catch coastal fogs in great walls of polypropylene mesh nets, which trap moisture and collect enough clean fresh water to supply entire mountain villages.*[1]

Access to plentiful and clean water is a global issue of tremendous importance. In this chapter, you will read a story and investigate case studies about water resources all over the world. Then you will evaluate where your water comes from and whether your supply could be threatened in the future.

Consider Investigate Process

Brainstorming

DISCUSS THE FOLLOWING with your partner and be prepared to share your ideas with the class. Don't worry if you don't know all the answers at this point. You will explore many of these questions in this chapter.

1. Earth is the only body in the solar system known to have liquid water on its surface. Many of the chapters in this course will discuss processes that involve water. Based on your current knowledge, discuss how water is involved in the following:
   a. weather
   b. photosynthesis
   c. the rock cycle
2. What do you know about water? Do you know of any qualities of water that make it unique?
3. Given that most of Earth's surface is covered with water, how do you think it is possible that water could become scarce for communities?
4. List your ideas about all the ways that you use water in a typical day, week, and year. (Save this list because you will use it later!)
5. Based on your current knowledge, where does your water come from? Draw and label a diagram starting with the faucet in your sink, and trace the water back as far as you can go. Do not use outside sources or ask others at this point—this should be your best guess based on what you already know!

Earth and the Solar System: Where Did the Water Come From?

Today, nearly 70% of Earth is covered by liquid water, but not a drop of liquid water has been found on any of the other terrestrial planets. Some water vapor was released to the atmosphere from volcanoes as Earth cooled early in the history of the solar system. However, the large amount of water that is present on Earth in comparison to other terrestrial bodies in the solar system cannot be accounted for by release from Earth's interior alone. So where did all this water come from, and why is Earth apparently the sole inheritor? Very little water was in the solar nebula at the time of the planets' formation. Planets closer to the Sun would have had the least amount of water due to the intense heat from the young star, but objects beyond the present-day orbit of Mars could have contained a considerable amount of water. Therefore, the majority of the water present on Earth today was probably a special delivery from the outer regions of the solar system.

Some scientists believe that comets may have supplied the bulk of oceanic water during the period of heavy bombardment, between about 4.5 and 3.8 billion years ago. Others think it is more likely that much of Earth's water came from protoplanets formed in the outer asteroid belt.

Several moons in the outer solar system such as Europa, Callisto, and Ganymede are thought to have liquid water beneath solid frozen surfaces. Surface features on Mars show evidence of flowing water in the planet's past, but it is believed that liquid water could not survive on Mars' surface today due to extremely low temperatures and atmospheric pressure. The Martian atmosphere is so thin that even if the temperature rose above freezing, the ice would change directly to water vapor.

WHAT'S THE STORY?

The following story talks about water shortages that have happened in some U.S. communities. Could it happen to you?

Water Running Dry

The year 2011 was a dry one for Texas. As of August 23, 2011, more than 80% of the state's land area was considered to be experiencing "exceptional drought" conditions (see Figure 2.1). The dry conditions caused wildfires to burn out of control in some parts of the state, and ranchers and farmers struggled to cope as cattle ponds and farm fields dried up.

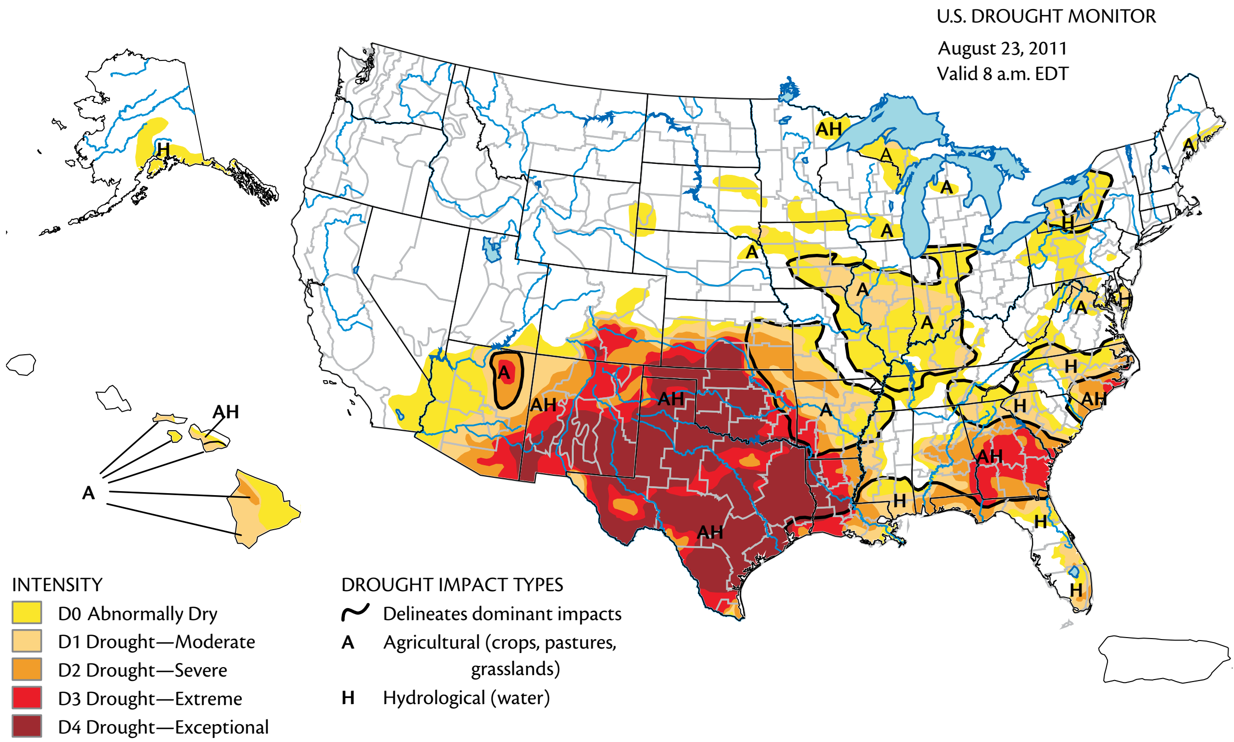


Table: Drought Severity Classification

CATEGORY	DESCRIPTION	POSSIBLE IMPACTS
D0	Abnormally Dry	Going into drought: Short-term dryness slowing planting, growth of crops, or pastures. Coming out of drought: Some lingering water deficits; pastures or crops not fully recovered.
D1	Moderate Drought	Some damage to crops and pastures; streams, reservoirs, or wells low; some water shortages developing or imminent; voluntary water-use restrictions requested.
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed.
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions.
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies.

FIGURE 2.1
Map showing areas of the United States that were experiencing drought conditions as of August 23, 2011. The table explains the possible impacts associated with each drought severity level.[2]

Even parts of the United States that thought they would never run out of water have experienced severe shortages. In May 2008, the southeastern United States was in the midst of a prolonged drought, as shown on the map in Figure 2.2.

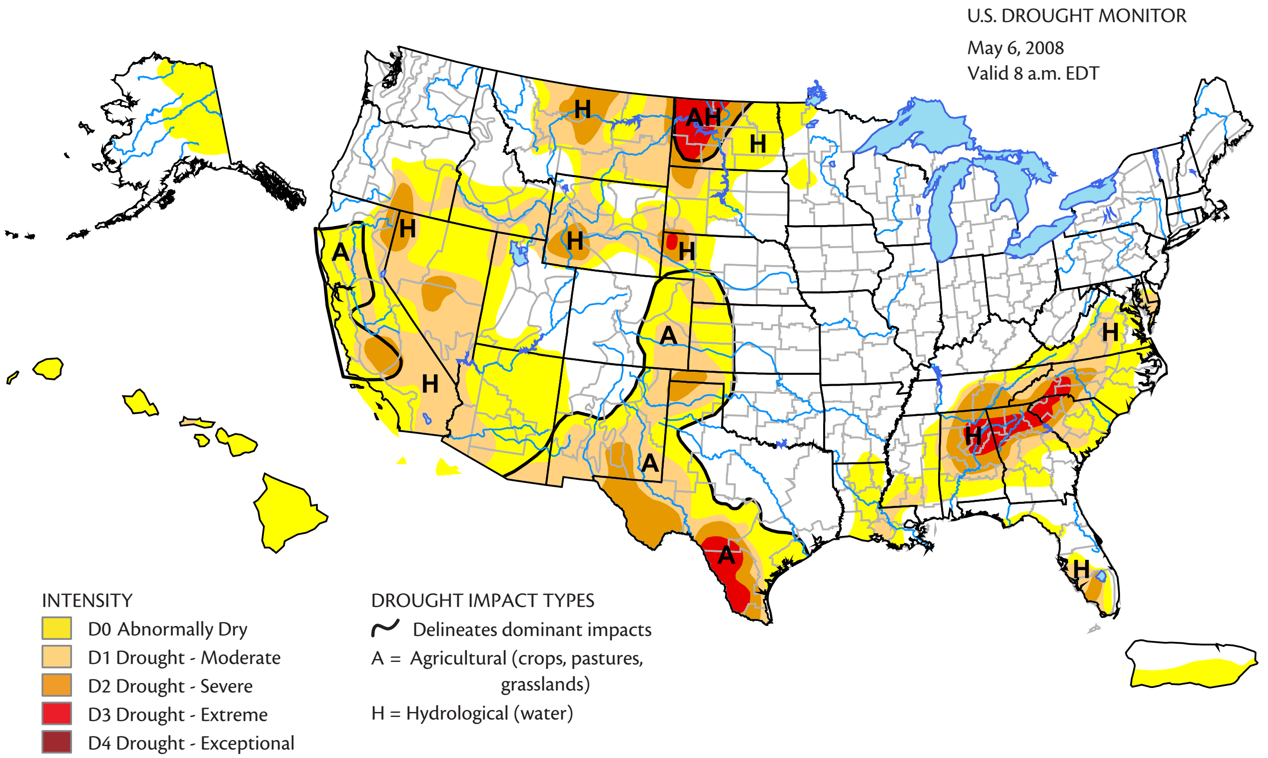


FIGURE 2.2
Map showing areas of the United States that were experiencing drought conditions as of May 2008.[3]

The lakes used as water supplies by Atlanta, Georgia, and Raleigh, North Carolina, reached dangerously low levels during this drought, and neighboring states began fighting over access to water. Georgia even challenged its boundary with Tennessee, saying Georgia's boundary should be moved north to include part of the Tennessee River.

During this 2007–2008 drought, the small community of Orme, Tennessee, was particularly hard hit. The people in this town relied on a waterfall-fed creek and a natural spring for its water supply, and these supplies dwindled to a trickle. They had to truck in water to fill the town's water tank, and the water supply to houses was shut off except for 3 hours every evening. A lifelong resident of Orme, Cheryl Evans said, as she rushed to do her dishes, laundry, and fill water jugs, "It's strange. I can't tell you how many times I've turned on the faucet before remembering the water's been cut."[4]

About the Reading

Write your responses to the following questions in your notebook. You won't find the answers to most of these questions in the story. Use your own knowledge and ideas, and be prepared to discuss your answers with the class.

1. Study the map in Figure 2.1. Use the legend, which explains the meaning of the colors. Which states experienced the worst drought conditions in August of 2011? Did your area experience drought?
2. Compare the map in Figure 2.1 to the map in Figure 2.2. How are the patterns in these maps similar? How are they different?

3. Have you or anyone in your family experienced drought? If so, what were some of the effects on people's lives?
4. If you were not able to obtain water as you do now and you had to find it yourself, where would you go to get it? How far would you have to go?

Water is clearly important to survival, and in some parts of the world, this precious resource is becoming scarce. How much do you use in a day? How much of that is critical and necessary? To gain a greater appreciation of your dependence on this resource, you will develop an estimate of your daily domestic water use in the following task.

TASK 1

How Much Water Do You Use?

In this task, use tables showing the amount of water used for typical domestic tasks to estimate your personal daily water use. Then you'll compare your daily use to that of your classmates and people in other parts of the world.

Procedure

Record all calculations and answers in your notebook as you work.

1. Look back at the list you developed during Brainstorming about all the ways that you use water in a day, week, and year. Add any more ideas you might have at this point. Then, using the water usage tables (Tables 21.–2.2), calculate the amount of water you use in a typical week for each of these activities. Here are a few suggestions:
   a. It will help you organize your work if you draw a table in your notebook that lists the activities, number of times per week (or other time period) you do that activity, and the number of gallons per week used.
   b. There may be some activities that you don't do to the same extent every week because they are seasonal (such as watering the lawn). You can come up with an estimate of the number of gallons used in a month or year, and then calculate the average weekly water use during a typical year for that activity.
2. Total your weekly water use for all the listed activities, and then divide this number by seven to obtain your daily water use.
3. Be prepared to share your results with your classmates.

Materials

- calculator

Table 2.1: Typical Rate of Water Use for Everyday Activities[5]

ACTIVITY	GALLONS USED (CONVENTIONAL)	GALLONS USED (WATER SAVING)
Toilet flushing	5–7 gallons per flush	1.5–3.5 gallons per flush
Shower (water running)	7–10 gallons per minute	2–4 gallons per minute
Bath (full tub)	36–50 gallons (conventional)	30–40 gallons (conventional) 40–80 gallons (whirlpool)
Laundry washing machine (full load)	As much as 40–60 gallons (top loader)/load	15–30 gallons (front loader)/ load
Dishwasher	15 gallons/normal load	7.5–10 gallons/normal load
Dishwashing by hand	30 gallons tap running/ load	10–20 gallons with stopper in sink/load
Shaving	20 gallons tap running/ shave	1–2 gallons water in sink/ shave
Brushing teeth	10 gallons tap running/ brushing	1–2 pints water in cup or glass/brushing
Using water from faucet for washing hands, etc.	1.5 gallons/minute (tap running)/hand wash	

Table 2.2: Typical Amount of Water Used
Each Time for Certain Activities[6]

ACTIVITY	GALLONS USED (CONVENTIONAL)
Cooking (meal/person)	3 gallons
Washing car	50 gallons by hand
	14 gallons at car wash
Watering lawn/garden (30 min)	240 gallons with garden hose

Analysis

Complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. According to a report written by the World Water Council in 2000, people in North America use an average of 92 gallons (348 liters) of water per day for domestic purposes. How did your estimate compare with this value? If your estimate was different, think about why and describe some possible reasons.

2. Compared to the 92 gallons of water per day used by Americans, Europeans use on average about 53 gallons (201 liters) of water per day, and in sub-Saharan Africa, people use only 3–5 gallons (11–19 liters) per day.
    a. Why do you think people in these other regions of the world use so much less than the average American?
    b. If you only had 3–5 gallons per day of water available to use, what would you use it for?
3. The United Nations recommends that people need a minimum of 13.2 gallons (50 liters) of water a day for drinking, washing, cooking, and sanitation. Is this reasonable? Explain your thinking.

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So far, you've focused on the ways you directly use water—for drinking, bathing, clothes washing, and the like. In reality, your water footprint is much bigger than that because you indirectly consume water in other ways. The following task will help you look at a bigger picture of the amount of water you require to support your way of life.

TASK 2

Thinking Beyond the Bathwater: Your Water Footprint

According to the study, *Estimated Use of Water in the United States in 2000,* Americans used a staggering total of 408 billion gallons of water per day in 2000, on average, including both direct and indirect uses of water. This is enough water to fill 8 billion bathtubs per day.[7] Even more surprising, this computes to 1,430 gallons per person per day! That number is without a doubt much higher than what you estimated in Task 1. In fact, statistics show that the domestic water use you have been measuring in your household actually represents less than 8% of the freshwater used in the United States.

So how can Americans consume so much water? To really understand how much water you use, you need to consider the water used to grow your food, as well as the water required to make the objects that you use. In this task, you will review some interesting data about water use in the United States and the world, and then analyze what it means.

Procedure

Study the information in *Background: Beyond the Bathwater.* Then write answers to the Analysis questions that follow and be prepared to discuss them with the class.

Background: Beyond the Bathwater

Have you ever considered the water that is used to produce the products you use and consume? Table 2.3 shows the estimated amount of water it takes to make some typical foods and other products.

Agriculture places the largest demand on freshwater resources. Approximately 40% of the freshwater used in the United States is for irrigation. Water is also used in industry and mining, for cooling in thermoelectric power plants, to water livestock, and for a variety of commercial purposes. Figures 2.3 and 2.4 show the estimated total water withdrawn (by state) for irrigation and industrial use during 2000. Figure 2.5 shows water usage patterns for general regions of the world.

(Continued on the following page)

Table 2.3: Water Used to Produce Various Products[8]

PRODUCT	AMOUNT OF WATER REQUIRED TO PRODUCE
One cup of coffee	37 gallons
One cup of milk	62 gallons
⅓ pound beef burger	660 gallons
One pound of rice	449 gallons
One pound of wheat	132 gallons
One board foot of lumber	5.4 gallons
One pound of plastic	24 gallons
One gallon of paint	13 gallons
One pound of wool or cotton	101 gallons
One refined barrel of crude oil	1,851 gallons
One ton of cement	1,360 gallons
One ton of steel	62,600 gallons
One automobile	36,000 gallons

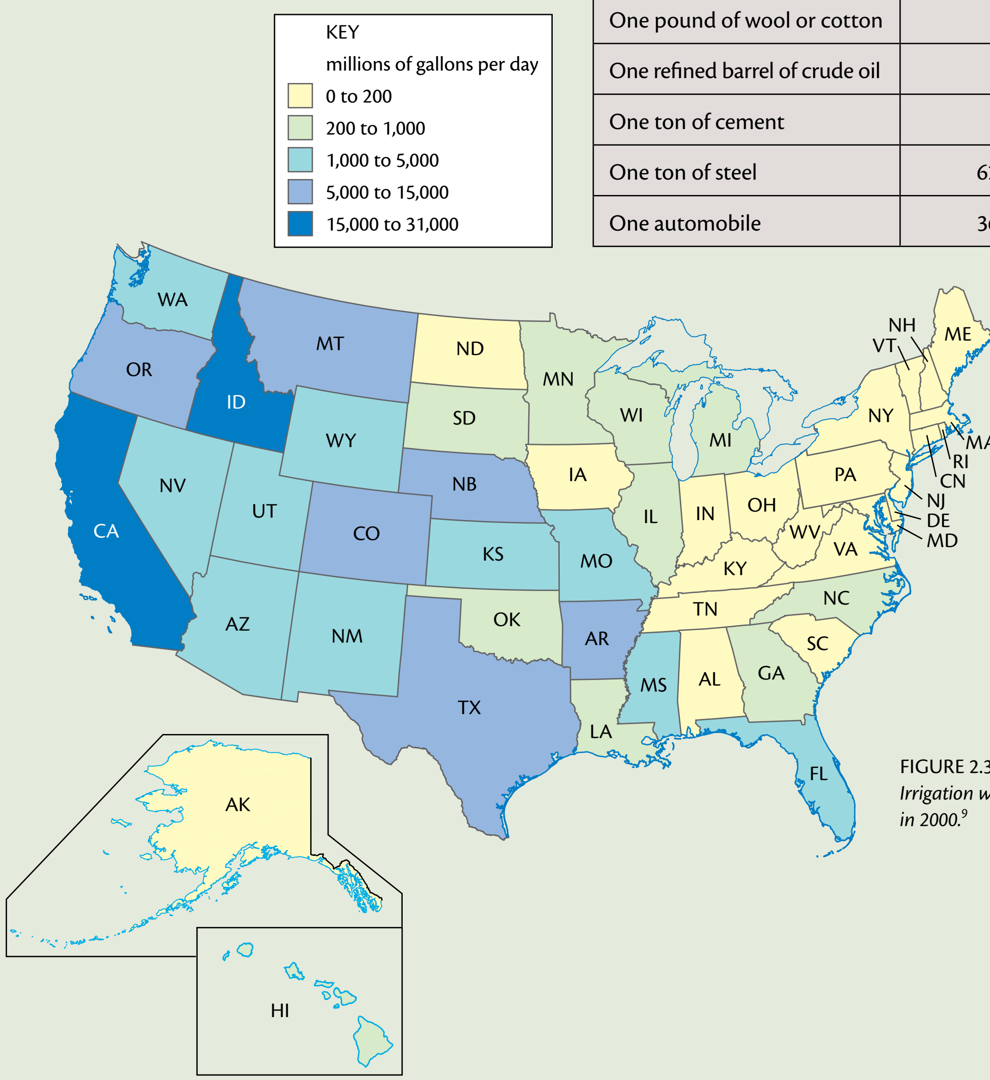


FIGURE 2.3
Irrigation withdrawals by state in 2000.[9]

Background: Beyond the Bathwater *(Continued from previous page)*

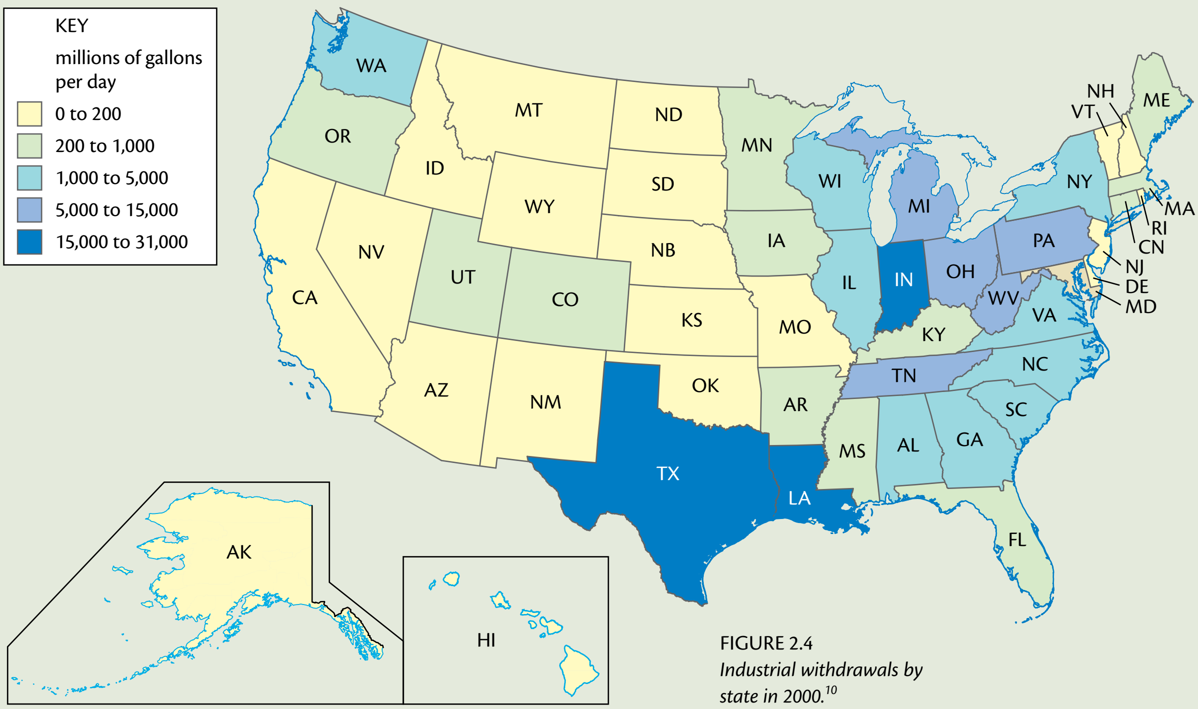


FIGURE 2.4
Industrial withdrawals by state in 2000.[10]

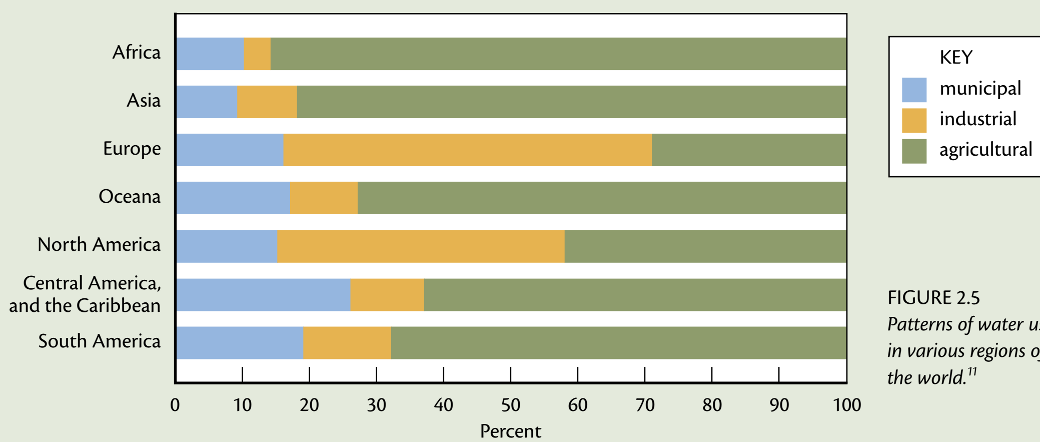


FIGURE 2.5
Patterns of water use in various regions of the world.[11]

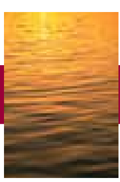
Analysis

Complete the following questions and record your answers in your notebook. Be prepared to discuss your answers with the class.

1. Study the information in Table 2.3, *Water Used to Produce Various Products,* and write down three thoughts or questions you have about these data.
2. According to Table 2.3, it takes 660 gallons (2,498 liters) of water to produce one beef burger but only 449 gallons (1,700 liters) of water to produce a pound of rice (about 10 servings). Based on any general knowledge you have about the steps involved in producing beef and rice, what ideas do you have about why it takes so much more water to produce beef?
3. Describe how you think water is used to produce an automobile.

4. Write three sentences about what the data in Figures 2.3 and 2.4 show about water usage for irrigation and industry in the United States. Based on your knowledge about different areas of the country, write down some reasons why these trends exist.
5. According to statistics compiled by the United States Geological Survey (USGS), Texas, California, and Florida used more water than any other states in 2000. List possible reasons for the heavier water use in these states.
6. During 2012, a severe drought hit much of the midwestern United States, and there was concern that food prices would rise. Explain how a lack of water in regions of the U.S. could cause food prices in your grocery store to increase.
7. How did your state's water use for irrigation and industry compare with other states during 2000? Compare your state to another that used more or less water and try to explain why the water use was different.
8. Write two sentences that describe patterns of worldwide water usage depicted in Figure 2.5. Then explain why the patterns of water usage are different from one region of the world to another.

As you study your personal use of water at home, as well as how dependent you are on water supplies elsewhere to produce your food and make products you use, you begin to appreciate the many ways you depend on and compete for this critical resource. In the Investigate challenge that follows, your goal will be to understand where your water comes from and how your supply might be threatened.



Consider **Investigate** Process

CHALLENGE

Where does your water come from?

Most people take water for granted, expecting it to flow freely from the faucet whenever the tap is turned on. This is one of the most important resources you use every day, but do you know where it comes from? Could you ever run out of water, like the people in Orme, Tennessee?

GATHER KNOWLEDGE

To learn more about where your water comes from, develop your background knowledge by 1) reviewing what you know about how water cycles through Earth's systems into useful freshwater sources; 2) modeling two types of water supplies: surface water and groundwater; and 3)researching water supply case studies from communities around the world to learn the ways that they get their water. Then you will be ready to design and perform your own investigation of your local water and potential threats to its supply.

You know from your study of Earth's systems in this and other science classes that water exists in three states on Earth: gas, liquid, and solid. Water is found in the atmosphere, on Earth's surface, and even within the ground. Not all of this water is useful to people for drinking, bathing, and watering crops—in fact, less than 1% of it is. Where are the sources of water that you can use, and how does the water get there?

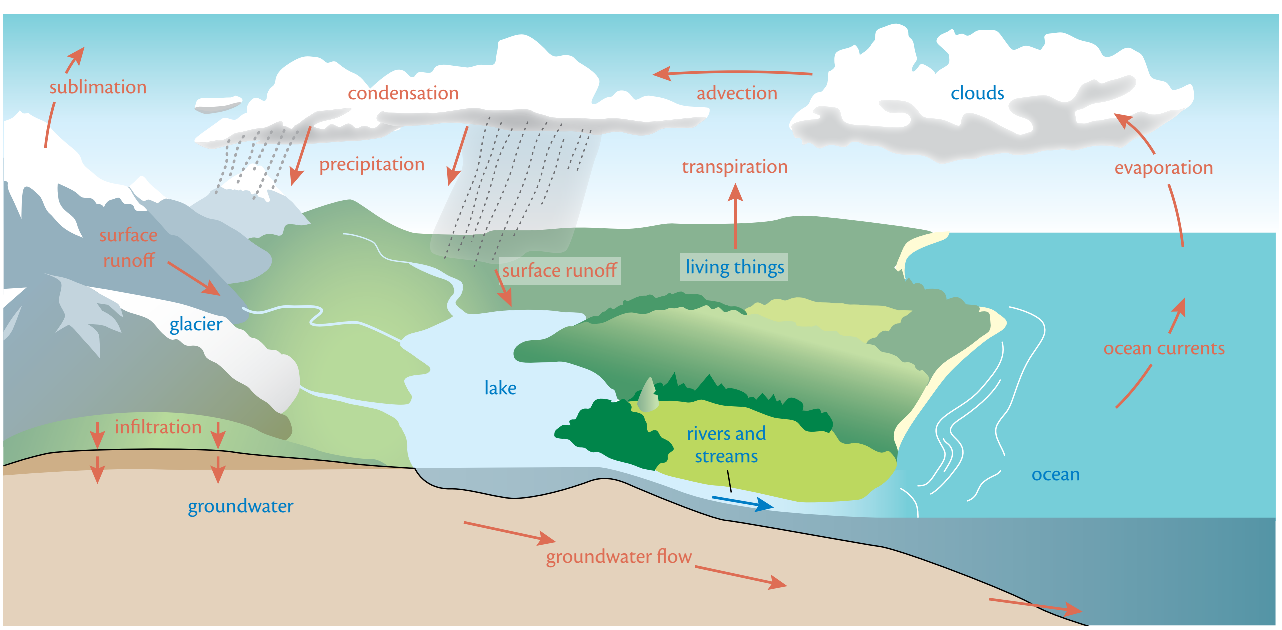
Water is naturally recycled through Earth's systems and is temporarily stored in reservoirs such as the oceans, the atmosphere, rivers, and living things. In the activity below, review and develop your understanding of how water moves through various reservoirs in Earth's systems, paying particular attention to the very small portion that resides in freshwater sources that people can use.

ACTIVITY 1

Reservoir Roulette: A Journey Through the Water Cycle

Earth's hydrosphere contains a tremendous amount of water, which is constantly being recycled, as shown in the water cycle diagram in Figure 2.6. In fact, each day the Sun evaporates one trillion (1,000,000,000,000) tons of water from Earth's surface!

FIGURE 2.6:
Water molecules cycle through Earth's systems by multiple pathways. Blue are reservoirs, in which water is stored, and red are processes by which water molecules move from one reservoir to another.[12]



A water molecule (H_2O) can travel through the water cycle in many different ways. For example, it may be evaporated into the atmosphere, flow down a stream, or ride the wind in a cloud (horizontal convective motion, or advection). Along the way, the H_2O may stay for a while in various reservoirs—the ocean, a mountain glacier, or even a living organism like you.

How could a water molecule get from the top of Mount Everest into a cup of homemade chicken soup in Iowa? Where else might it end up along the way? In this activity you'll adopt an H_2O molecule, be told where it is and where it will end up, and then use your knowledge of the water cycle to take it on a journey through the atmosphere, hydrosphere, geosphere, and biosphere.

Procedure

1. Your teacher will assign your team a scenario that describes the beginning and ending points of your molecule's journey. Record these at the top of Student Sheet 2.1: *A Molecule's Journey Through the Water Cycle*. Read *Reservoir Roulette: Rules & Hints* on the next page.
2. You will work with two types of cards, Travel and Reservoir Cards. Take a quick look at them and briefly describe the major difference between the two types of cards. *Hint:* Looking at Figure 2.6, the water cycle diagram, might help.
3. Begin your molecule's journey by using your Reservoir Roulette spinner. Record your Destination Reservoir in the first column of the top row of Student Sheet 2.1.
4. Look through your Travel Cards and try to find a way for your molecule to get from its starting point to the destination reservoir that you spun in Step 3. If you can't use a single method of travel, figure out an intermediate reservoir and two methods of travel (one from current to intermediate and another from intermediate to destination reservoir).

   Remember that your H_2O molecule's ultimate goal is to make it to your scenario's ending point!

Materials

FOR EACH GROUP OF STUDENTS

- 1 scenario from Figure 2.7 (assigned by your teacher)
- set of Water Cycle Cards (11 Travel Cards and 8 Reservoir Cards)
- 1 Reservoir Roulette spinner
- poster paper
- markers of various colors

FOR EACH STUDENT

- Student Sheet 2.1: *A Molecule's Journey Through the Water Cycle*

FIGURE 2.7
Scenarios for Activity 1

RESERVOIR ROULETTE—A JOURNEY THROUGH THE WATER CYCLE

SCENARIO 1
From the top of Mount Everest to a cup of homemade chicken soup in Iowa

SCENARIO 2
From your community swimming pool to the Mediterranean Sea

SCENARIO 3
From ice in Glacier National Park to a can of lime soda in China

SCENARIO 4
From the water fountain in your school to Niagara Falls

SCENARIO 5
From a crayfish in the Mississippi River to the Nile River

SCENARIO 6
From a snowbank in Wisconsin to the Indian Ocean

SCENARIO 7
From a Galapagos finch to a wolf in Siberia

SCENARIO 8
From the Pacific Ocean to an apple pie in Indiana

SCENARIO 9
From an oak tree in California to a water well in New Hampshire

SCENARIO 10
From a tomato plant in Texas to a rain cloud in Maine

SCENARIO 11
From a pot of water on your stove to an iceberg in the North Atlantic

Reservoir Roulette: Rules & Hints

- You must go to at least four "spun" reservoirs.
- Because your molecule may go to the same type of reservoir more than once and must move around the world, you should name each specific reservoir (for instance, the Nile River) or at least provide a general location (for instance, North Africa).
- Humans cannot intentionally move your water molecule.
- Your molecule cannot get from an ocean to a river using only one Travel Card.

If you spin the same reservoir two times in a row: Your molecule will have to leave the reservoir, then return. It can move to the same type of reservoir in a different location on Earth, but it cannot get there using only one Travel Card.

If you spin a reservoir that is very far from your current location: Look carefully through the Travel Cards to see if there is any single method for your molecule to get to this next destination. Could it travel into the atmosphere and get blown by the wind? Or enter an ocean or river and get carried along by a current? Get into a fish or bird and migrate there?

If you can't find a single method that will work, go to an intermediate reservoir

a. that your molecule can get to with a single Travel Card and
b. from which your molecule can reach the reservoir you spun.

5. Use the third column of the top row of Student Sheet 2.1 to describe your water molecule's journey to its next reservoir (including any intermediate ones if necessary).
6. Repeat Steps 3–5 at least three times, or as many as it takes, until you have reached a reservoir from which you can use a single travel method to reach the ending point of your scenario. Each time you spin a new destination use a new row of Student Sheet 2.1 to describe that leg of your molecule's journey. Use the last row for your scenario ending point.

   If needed, you can make additional rows for Student Sheet 2.1 on the back of your sheet or on a new piece of paper
7. Use the next row of Student Sheet 2.1 to fill in your end point destination and complete the description of the final leg of your molecule's journey.
8. Prepare to present your H_2O molecule's trip to your classmates. Using poster paper and markers, draw a simple diagram or sketch of your water molecule's journey. Your diagram should be creative and interesting, and should clearly show:
   a. your starting point and your end point
   b. each reservoir your molecule went to along the way
   c. how your molecule traveled from each reservoir to the next
9. Present your trip to your classmates. Be prepared to explain the water cycle processes described on your diagram.
10. Write answers to the analysis questions and be prepared to share them with the class.

Analysis

Use the following questions to think about how humans are connected to the water cycle. Record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. Describe two different pathways a water molecule might follow through the water cycle to get from a mountain glacier to the ocean. Describe the processes and reservoirs involved.
2. Using your water cycle diagram as a resource, identify and describe the points in the cycle where humans might be able to access freshwater.
3. To be drinkable, water must not only be fresh (rather than saltwater), but also clean. Based on your prior experience, describe the ways that water can become contaminated as it cycles through Earth's systems.
4. What are some reasons that certain communities might have more freshwater available to use than others? Relate your answer to the water cycle.
5. Humans interfere with the natural water cycle by building dams and artificial surface-water reservoirs. Based on your prior experience, what are the reasons that people do this?
6. Water is constantly cycling through Earth's systems, and freshwater sources are continually replenished. Given this fact, how is it possible for freshwater to become scarce in a community?

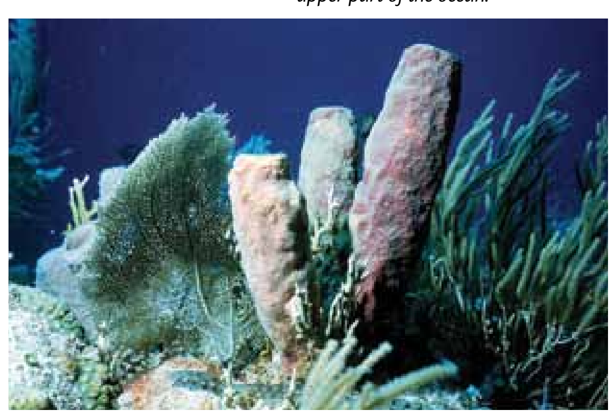
READING

The Unique Qualities of Water

It may be tempting to take water for granted. But water has unique qualities that make it absolutely essential to human survival. In fact, water is critical to the functioning of all of Earth's systems. For example, water is the only substance that occurs naturally in three states (solid, liquid, gas) on Earth's surface. Water expands when it freezes, unlike most other substances, causing ice to float on liquid water. Without this property, water bodies such as lakes and seas would freeze from the bottom up.

Water also has the highest **heat capacity** (ability to store heat) of all common solids and liquids. This is why ocean water is so effective at storing heat and transporting it from the equator toward the poles, and also why the climate near the coast is so different from inland climates (you'll learn more about this in Chapters 3 and 4). The transparency of water to light allows plant life to grow in the upper part of the ocean, as well as in lakes and other water bodies on Earth's surface (Figure 2.8).

FIGURE 2.8
The transparency of water to light allows ecosystems with organisms such as these tube sponges to thrive in the upper part of the ocean.



Water makes up most of the human body, and it is critical to metabolic processes. It is uniquely effective in dissolving and transporting substances, and the high surface tension of water is important to the processes that happen in your cells. That's why to survive, humans must consume water every day by drinking and by eating food that incorporates water. Humans have evolved to live on this planet, where water is plentiful. However, consumable water isn't always easy to find. To help you think about where your water comes from, in the next activity you'll investigate the sources of water people use.

About the Reading

Write your responses to the following questions in your notebook, and be prepared to discuss your answers with the class.

1. A new term—heat capacity—was introduced in this reading. Start a list of terms in your notebook and write down what this term means. Leave space to add to or modify this definition as you learn more about it. You will be investigating and thinking about this concept more in later chapters.
2. What are some of the unique qualities of water that make it so important to living organisms?
3. Describe ways that you think Earth would be different if:
   a. water didn't have a high heat capacity.
   b. water didn't expand when frozen.

ACTIVITY 2

Where's the Drinking Water?

With all of Earth's water, it may seem surprising that anyone could face a shortage. So much water is found cycling through the oceans, clouds, ice, and land. However, it is less surprising when you realize that only 2.5% of the water in the hydrosphere is fresh (not saltwater). Also, only about 0.007% of that water is readily accessible for human use (Figure 2.9). As a comparison, if all of Earth's water fit in a gallon jug, the available freshwater would equal just over a tablespoon. This tiny fraction of Earth's water is found in lakes, rivers, and artificial reservoirs on the surface. It is also found in **groundwater** (water beneath Earth's surface) shallow enough to be tapped.

Does your water come from surface water or groundwater? To understand where your water comes from, you should know some basics about these two water sources. In this activity, you'll model how surface water and groundwater collect in reservoirs and aquifers that people can use.

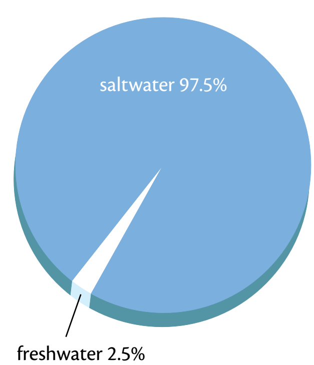


FIGURE 2.9:
Only 2.5% of the water in the hydrosphere is freshwater. Most of it is locked up in glacial ice or in groundwater aquifers too deep to affordably access.

Part A: Modeling a Watershed

Background: Surface-Water Supplies

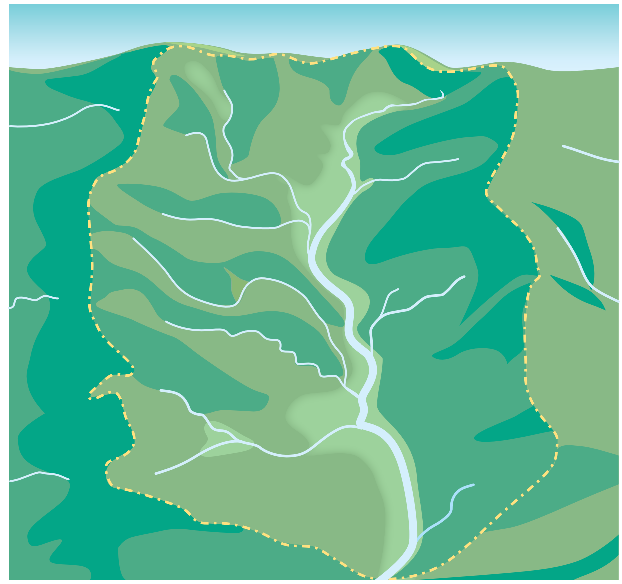


FIGURE 2.10:
The watershed of a river.

A large amount of the water used by communities comes from rivers, streams, and lakes on the land surface. Figure 2.10 illustrates the concept of a **watershed** (also called a drainage basin). A watershed is the entire land area that drains to a given river, stream, wetland, or lake. Surface-water runoff within a certain watershed drains and then collects at the lowest point. (In the case of a river, the lowest point may be a wetland, lake, or the ocean). The boundary of a watershed is called a water **divide.** Any water that falls outside of that boundary will flow in another direction.

The amount of surface water available to a community depends on the size of the watershed in an area and the region's climate. Some areas have more precipitation (snow and rainfall) than others. Precipitation also varies from year to year. Some regions have wet and dry seasons. These communities may have more surface water than they need during the wet months of the year. However, they might have less water than they need during the dry months of the year. Many communities build reservoirs to store water, just like a natural lake. This ensures there is adequate water during dry years and dry seasons. They build these reservoirs by constructing dams along rivers. This allows water to flood the land just up river (Figure 2.11). These dams can also be used to generate hydroelectric power and to protect downstream areas from flooding.

Now, use a watershed model to investigate how surface water that people can use collects in reservoirs.

FIGURE 2.11
The Hoover Dam collects water from the Colorado River near Las Vegas, Nevada. In addition to storing water, the dam is also used to generate electricity.

Procedure

Record your observations in your notebook as you work.

1. Examine the relief map in your Watershed Tray and find the highest point. In your notebook, make a labeled sketch of the relief map and label it Drawing #1. Show the location of the major mountains, hills, ridges, and valleys.
2. Make a prediction. If you were to gently empty a pipet full of water over the center of the relief map, where would most (or all) of the water go? Use the blue pencil to draw your predicted water flow path on Drawing #1. Briefly explain the reasoning that led you to your prediction.
3. Fill the pipet with water from the reservoir in your Watershed Tray. Position the filled pipet about 2 cm above the center of the relief map. Gently release all the water from the pipet. In your notebook, describe how your observations of the water flow do or do not agree with your prediction.
4. Imagine that a heavy rain falls over the entire area of the relief map. Use the blue pencil on Drawing #1 to show where you think river(s), lake(s), or other bodies of water would appear after the rain.
5. Gently release several pipets full of water over the entire area of the relief map. Do this until you think you understand where the water flows after it falls onto all parts of the map. If needed, you can reuse water that has collected in the moat surrounding the map.
6. Use the blue pencil to draw a new sketch and label it Drawing #2. Show where you observed bodies of water, such as rivers and lakes, forming. Use arrows to indicate the direction of water flow.
7. Look carefully at the relief map and the blue bodies of water you sketched on Drawing #2. Use the red pencil to draw in the boundaries of the watershed for each water body you drew on your sketch.
8. If a town wanted to build a dam to collect and store water for its supply, where would the best place be to build it? Where would it likely collect the most water? Experiment more with your model to figure this out. Use the modeling clay to simulate a dam. Then draw a new sketch and label it Drawing #3. Show the location of your dam and where water would collect behind your dam. Explain your reasoning for placing the dam in this location.
9. Write answers to the following questions in your notebook:
   a. How many major rivers did you observe?
   b. How many streams did you observe feeding water into the rivers?
   c. What determines the boundary between two watersheds?
   d. Is the entire area of the relief map part of the same watershed? Explain why or why not?

Materials

FOR EACH GROUP OF STUDENTS

- 1 Watershed Tray
- 1 pipet
- 2 red/blue pencils
- modeling clay

Analysis for Part A

When you've finished working with your model, think about the following questions. They will challenge you to think more deeply about what you learned from your observations. Write your responses in your notebook. Be prepared to discuss your answers with the class.

1. The following new terms were introduced in this activity: *watershed* and *divide*. Write the meaning of these terms in your notebook, based on what you understand from the activity. Leave space to revise these definitions as you come to understand them better.
2. A few inches of rain in a region can cause the level of water in a river to rise much more than a few inches. Explain why, using the concept of a watershed.
3. Describe how the size of a watershed and a region's climate can affect the amount of surface water available in a particular area.
4. Answer the following questions about dams and artificial surface-water reservoirs:
   a. Why do some communities build dams and reservoirs?
   b. What determines the amount of water that will collect in a surface-water reservoir?

Part B: Groundwater Model

My water touches the dirt?!

—Anonymous high school student
from New Hampshire

Many communities (perhaps yours!) use groundwater as a drinking water supply. That means the water comes from the ground beneath your feet. Where, exactly, is the water? How does a well draw water out of the ground? Next, you'll build a model to help you visualize groundwater and how water wells work.

Background: Groundwater Supplies

About half the people in the United States use groundwater as their primary water supply. As shown in Figure 2.12, sometimes this water is stored in fractures or other spaces within the bedrock. Often the water is stored in the spaces between loose earth materials—sand, silt, and clay—that lie above the bedrock. These loose earth materials may be thin to nonexistent, or may be hundreds of feet thick. Figure 2.12 is simplified, because it has an even thickness of loose earth material, and it doesn't show the layers of sand, silt, and clay that are typically present. When precipitation seeps into the ground, it sinks due to gravity and collects in the spaces between the sand, silt, and clay particles, and in fractures and cavities in bedrock. Groundwater also flows very slowly from high areas to low areas, and it can seep into streams, rivers, lakes, wetlands, or oceans.

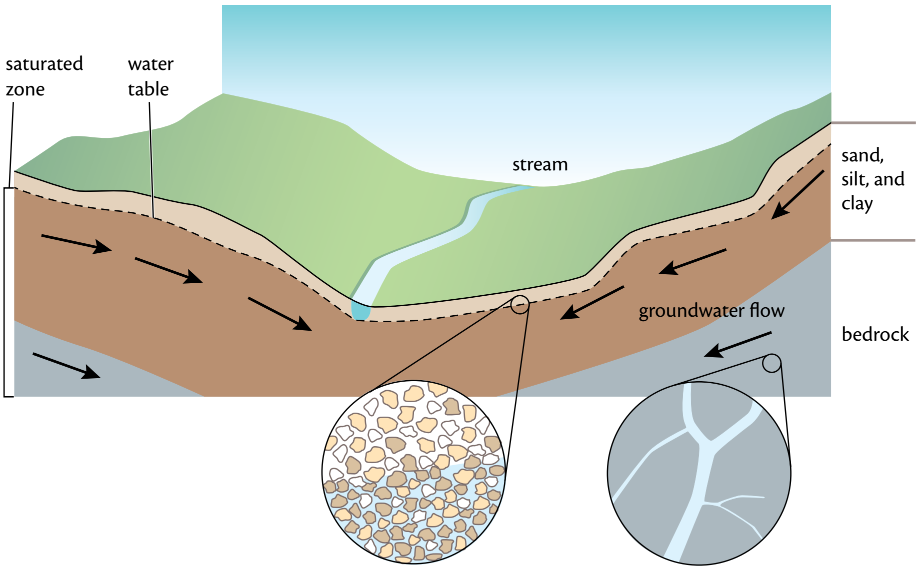


FIGURE 2.12
Groundwater collects and flows through the pore spaces between soil particles and bedrock fractures.

Groundwater **aquifers** are loose earth material or rock zones through which water can easily move. Groundwater moves through sand and highly fractured bedrock fairly easily. Water moves very slowly through fine-grained silt and clay layers or bedrock with few fractures, or cavities that aren't connected. Figure 2.13 shows how the porosity varies depending on the size and sorting of loose particles. **Porosity** is the amount of space available to hold water. The aquifer has a higher **permeability** (a measure of the ability of a material to let water pass through) when it contains large, interconnected pore spaces, more fractures, or connected rock cavities.

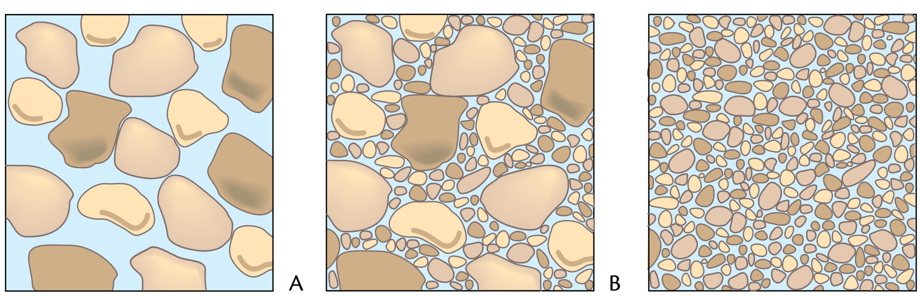


FIGURE 2.13
The three diagrams show water held in pore spaces between particles of sand and silt. The materials in B and C have smaller pore spaces, so they are less permeable.

You may wonder if there is groundwater in your area. Dig down into the ground anywhere and you will eventually hit material or rock that is saturated with water. This water-filled material and rock is called the **saturated zone.** In some areas, the saturated zone is very shallow and may even intersect the surface. (This is generally the case near lakes and wetlands.) At other locations, such as in more arid climates, you must dig down hundreds of feet to reach the **water table,** the top of the zone that is saturated with groundwater, shown in Figure 2.12. The amount of groundwater that can be produced also varies according to the amount of precipitation that has fallen in the region. The rain and snow that fall on the surface replenish the aquifer as water seeps into the ground and moves downward to the water table. This downward movement of water through the ground is known as **infiltration.** The amount of water that can be produced also varies according to the materials that make up the aquifer. For example, some areas have thick layers of sand with high porosity and permeability. Those areas are more likely to have highly productive groundwater aquifers.

Figure 2.14 shows wells that have been drilled into the ground to access a groundwater aquifer. Sometimes, the groundwater flows naturally to the surface through the wells because the water is under pressure underground. These are **artesian** wells. More often, the groundwater needs to be pumped to the surface. In many areas of the United States away from cities, people have groundwater wells at their homes. In other areas, community water wells are drilled to serve many homes and businesses. Groundwater is often used for drinking water supplies, because it is naturally filtered and cleaned underground. Figure 2.14b shows what happens if water is pumped out of an aquifer at too high a rate. This lowers the water table (just as a drought would) and can leave some wells dry.

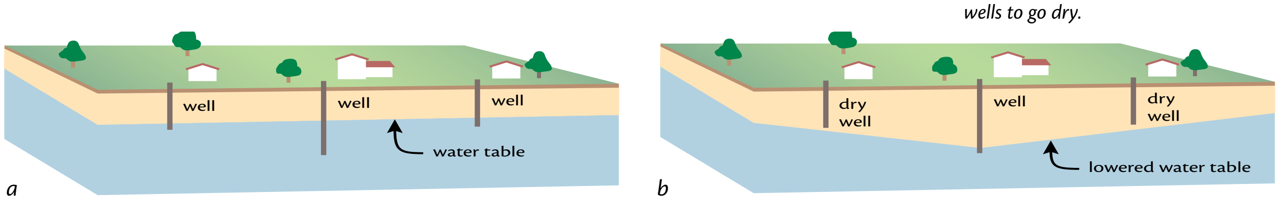


FIGURE 2.14
Diagram A shows the position of the water table before pumping of the center well begins. Diagram B shows the position of the water table after heavy pumping. The middle well is pumping water out of the aquifer at too high a rate, which has caused the other two wells to go dry.

Now, build a model to help you visualize a groundwater aquifer and how water moves through the ground to a drinking water well. Gather the listed materials and follow the steps of the procedure.

Materials

FOR EACH GROUP OF STUDENTS

- 1 clear cylindrical bottle
- 2 30-mL graduated cups
- 1 magnifier
- 1 3-mL pipet
- access to: red sand, white sand, gravel, silt, clay, blue-colored water

FOR EACH STUDENT

- 1 red/blue pencil
- Student Sheet 2.2: *Groundwater Modeling*

Procedure

1. With your group, observe and compare each of the five earth materials you have to work with and write descriptions of each one. To observe the samples, place a small amount of each type of material on a white piece of paper. The silt and clay may tend to form clumps—if so, break them up so that you can get a sense of the size of the individual particles. Use your magnifier to look at them closely. Rub a small amount of each of them between your thumb and index finger. This will make it easier for you to sense and compare the size of particles that may be too small to see.
2. Decide the order of the five layers you will put into the cylindrical container. You can choose the order of the layers, except do not put silt or clay directly above a gravel layer (it will fall between the cracks!) or have silt or clay as your topmost layer.

3. Use the following guidelines to create your model by placing the earth materials into the cylindrical container:
    - The sand and gravel layers should be 2–3 cm thick (40–60 mL of material).
    - The silt and clay layer(s) should be 1–2 cm thick (20–40 mL of material).
    - The layers do not have to be perfect but they should be fairly even and level.
4. Use the red end of your pencil to sketch and label your completed model in each of the four spaces labeled Drawing #1, Drawing #2, Drawing #3, and Drawing #4 on Student Sheet 2.2: *Groundwater Modeling.*
5. Imagine a light rain falls on your model. Predict what will happen to the rainwater after it hits the top layer.
    a. Briefly describe where you think the rainwater will go and how you think each different earth material will affect the movement of the water.
    b. Use the blue end of your pencil to draw arrows in Drawing #1 on Student Sheet 2.2 to show the path you predict the rainwater will follow after it hits the surface.
6. Repeat Step 4 except this time, imagine that it rains twice as much. Use Drawing #2 on Student Sheet 2.2 to draw in your predicted path.
7. Now, you will simulate light rain falling on your model and test your predictions.
    a. Gently pour 20 mL of colored water evenly onto the surface of your model.
    b. Observe very carefully what happens. Pay particular attention to what happens as water reaches the different layers. You may have to wait a while for the water to infiltrate as far as it can. Record your observations as precisely as possible.
    c. Sketch and label your observations on Drawing #3 on Student Sheet 2.2. If you can see them, label the water table, the unsaturated zone, and the saturated zone.

    Note: If water makes a "lake" on top, this means the water table is above ground. If this occurs, wait a few minutes to see if it infiltrates and if not, use the pipet to carefully remove the surface water.
8. Test your heavy rain prediction by repeating Step 7a–c. Use Drawing #4 on Student Sheet 2.2 for your sketch.
9. Now, you will simulate what happens when a well is drilled to obtain drinking water.
    a. Squeeze the bulb on your pipet and, keeping it squeezed, position the pipet over the center of your model and carefully push the pipet straight down until its tip "has drilled down" to the middle of your top layer.
    b. Slowly release the bulb and carefully observe what happens. Record your observations in your notebook.

c. Remove the pipet and describe anything it may have extracted.

d. Aim the pipet into a cup and gently squeeze the bulb to push out its contents.

e. Repeat Steps a–d four more times, each time using the same hole but pushing the pipet in a little more so that you drill down to the middle of the next lower layer.

Analysis for Part B

Write your responses to the following questions in your notebook. Be prepared to discuss your answers with the class.

1. A number of new terms were introduced in this activity: *aquifer, porosity, permeability, saturated zone, water table,* and *artesian.* Write the meaning of these terms in your notebook, based on what you understand from the activity. Leave space to revise these definitions as you come to understand them better.
2. Clay and silt can create layers called *aquitards.* Use evidence from this activity to explain what you think an aquitard is and why you were instructed not to have clay or silt as your topmost layer.
3. Compare your predictions (Drawings #1 and #2) with your observations (Drawings #3 and #4). Describe what, if anything, happened as you predicted, and what surprised you the most.
4. Summarize, using evidence from your observations,
   a. what happened when it "rained" on your model. Use water cycle terms you learned in Activity 2 (such as precipitation and infiltration).
   b. how the different types of earth materials affected groundwater movement.
5. If you were going to drill a well into your model, which layer would you drill down to in order to produce water at the highest rate? Explain your thinking.
6. Relate your model to an actual groundwater aquifer and explain, using terms related to the water cycle, why a groundwater well might go dry if a prolonged drought happened.
7. Why is the water table shallow in some areas on Earth and deeper in others? Use the information in this activity, your knowledge of the water cycle, and your own ideas.