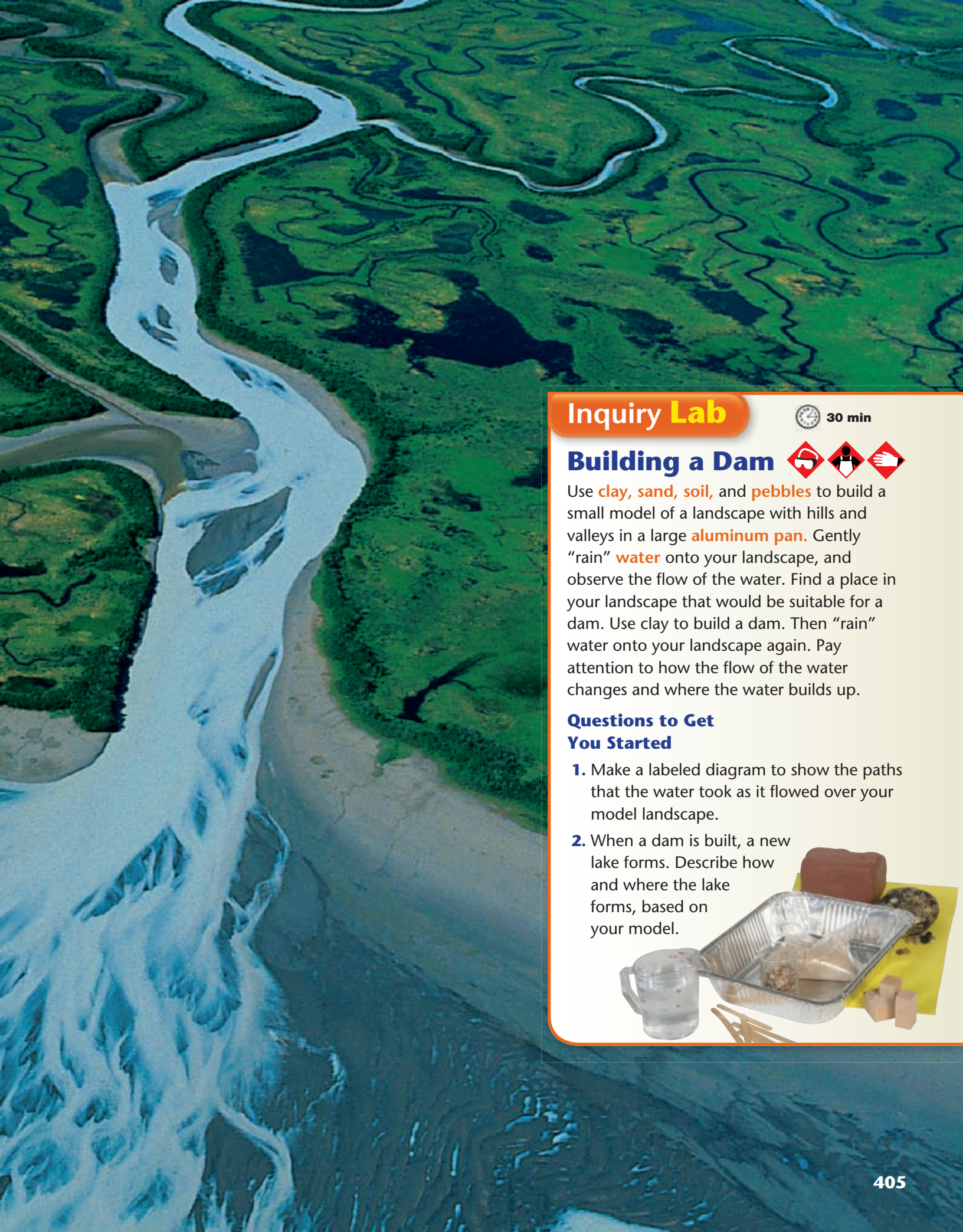
Chapter 15 River Systems

Chapter Outline

Why It Matters

Water sustains life. Water can also threaten life, in natural disasters called floods. People study river systems to better understand river erosion and deposition—processes that affect humans and shape the land.



Inquiry Lab

30 min

Building a Dam

Use **clay, sand, soil,** and **pebbles** to build a small model of a landscape with hills and valleys in a large **aluminum pan.** Gently "rain" **water** onto your landscape, and observe the flow of the water. Find a place in your landscape that would be suitable for a dam. Use clay to build a dam. Then "rain" water onto your landscape again. Pay attention to how the flow of the water changes and where the water builds up.

Questions to Get You Started

1. Make a labeled diagram to show the paths that the water took as it flowed over your model landscape.
2. When a dam is built, a new lake forms. Describe how and where the lake forms, based on your model.

READING TOOLBOX

These reading tools will help you learn the material in this chapter.

Word Parts

Suffixes The suffixes *-ion* and *-ation* turn verbs into nouns. For example, the verb *cooperate* means "to work together." Adding the suffix *-ion* forms *cooperation,* a noun that means "the process of working together."

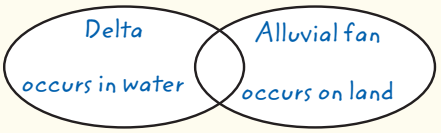
Your Turn In Section 1, the key terms *condensation, precipitation,* and *desalination* contain the suffix *-ion* or-*ation*. Identify the verb that each term came from, and write its definition. Record your notes in a table like the one started below. The key term *evapotranspiration* also contains the suffix *-ation*. Split this key term into its component words—*evaporation* and *transpiration*—and add these words to your table.

KEY TERM	RELATED VERB	DEFINITION OF VERB
condensation		
precipitation		
desalination	desalinate	to remove salt from something

Graphic Organizers

Venn Diagram A Venn diagram is useful for showing characteristics that topics share and characteristics that are unique to each topic. As you read, look for topics that have both shared and unique characteristics, and draw a Venn diagram to show how the topics are related.

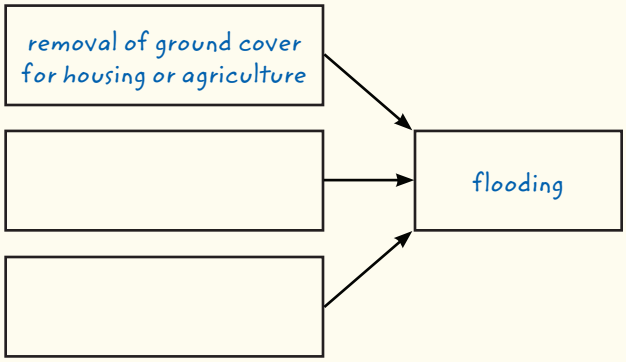
Your Turn In Section 3, you will read about deltas and alluvial fans. Make a Venn diagram like the one started below, and fill it in with shared and unique characteristics of these two types of sediment deposits.



Graphic Organizers

Cause-and-Effect Maps A cause-and-effect map can help you illustrate how, when, or why one event causes another event.

Your Turn As you read Section 3, create a cause-and-effect map like the one started below to help you study the causes and effects of flooding. Remember that you may include as many cause boxes and as many effect boxes as you need.



For more information on how to use these and other tools, see **Appendix A.**

SECTION 1

The Water Cycle

Key Ideas	Key Terms	Why It Matters
› Outline the stages of the water cycle. › Describe factors that affect a water budget. › List two approaches to water conservation.	**water cycle** **evapotranspiration** **condensation** **precipitation** **desalination**	Your survival depends on water, which makes up about two-thirds of your body. When you breathe out, you release water vapor, which becomes part of the water cycle.

The origin of Earth's water supply has puzzled people for centuries. Aristotle and other ancient Greek philosophers believed that rivers such as the Nile and the Danube could be supplied by rain and snow alone. It was not until the middle of the 17th century that scientists could accurately measure the amount of water received on Earth and the amount flowing in rivers. These measurements showed that Earth's surface receives up to 5 times as much water as rivers carry off. So, a more puzzling question than "Where does Earth's water come from?" is "Where does the water go?"

Movement of Water on Earth

Water is essential for humans and all other organisms. Its availability in different forms is critical for the continuation of life on Earth. More than two-thirds of Earth's surface is covered with water. Water flows in streams and rivers. It is held in lakes, oceans, and icecaps at Earth's poles. It even flows through the rock below Earth's surface as groundwater. Water is found not only in these familiar bodies of water but also in the tissues of all living creatures. In the atmosphere, water occurs as an invisible gas. This gas is called *water vapor*. Liquid water also exists in the atmosphere as small particles in clouds and fog, as shown in **Figure 1.**

water cycle the continuous movement of water between the atmosphere, the land, and the oceans

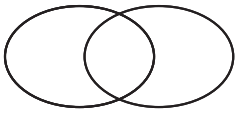
Earth's water is constantly changing from one form to another. Water vapor falls from the sky as rain. Glaciers melt to form streams. Rivers flow into oceans, where liquid water escapes into the atmosphere as water vapor. This continuous movement of water on Earth's surface from the atmosphere to the land and oceans and back to the atmosphere is called the **water cycle.**

Figure 1 The snow, the fog, and the river water in this photo are three of the forms that water takes on Earth. Invisible water vapor is also present in the air.

READING TOOLBOX

Venn Diagram

Make a Venn diagram with two circles. Label one circle "Transpiration" and the other circle "Evaporation." In the area where the circles overlap, write shared characteristics. In each of the other areas, write characteristics that are unique to each process.



Evapotranspiration

The process by which liquid water changes into water vapor is called *evaporation*. Each year, about 500,000 km^3 of water evaporates into the atmosphere. About 86% of this water evaporates from the ocean. The remaining water evaporates from lakes, streams, and the soil. Water vapor also enters the air by *transpiration*, the process by which plants release water vapor into the atmosphere. The total loss of water from an area, which equals the sum of the water lost by evaporation from the soil and other surfaces and the water lost by transpiration from organisms, is called **evapotranspiration.** Evapotranspiration is one part of the water cycle, which is shown in **Figure 2.**

Condensation

Another process of the water cycle is *condensation*. **Condensation** is the change of state from a gas to a liquid. When air rises in the atmosphere, it expands and cools. As the air cools, the water vapor it contains becomes cooler, and some of it condenses, or changes into tiny liquid water droplets, forming clouds.

Precipitation

The third major process of the water cycle is *precipitation*, the process by which water falls from the clouds. **Precipitation** is any form of water that falls to Earth's surface from the clouds and includes rain, snow, sleet, and hail. More than 75% of all precipitation falls on Earth's oceans. The rest falls on land and becomes runoff or groundwater. Eventually, almost all of this water returns to the atmosphere by evapotranspiration, condenses, and falls back to Earth's surface to begin the cycle again.

Reading Check **List the forms of precipitation.** (See Appendix G for answers to Reading Checks.)

evapotranspiration the total loss of water from an area, which equals the sum of the water lost by evaporation from the soil and other surfaces and the water lost by transpiration from organisms

condensation the change of state from a gas to a liquid

precipitation any form of water that falls to Earth's surface from the clouds; includes rain, snow, sleet, and hail

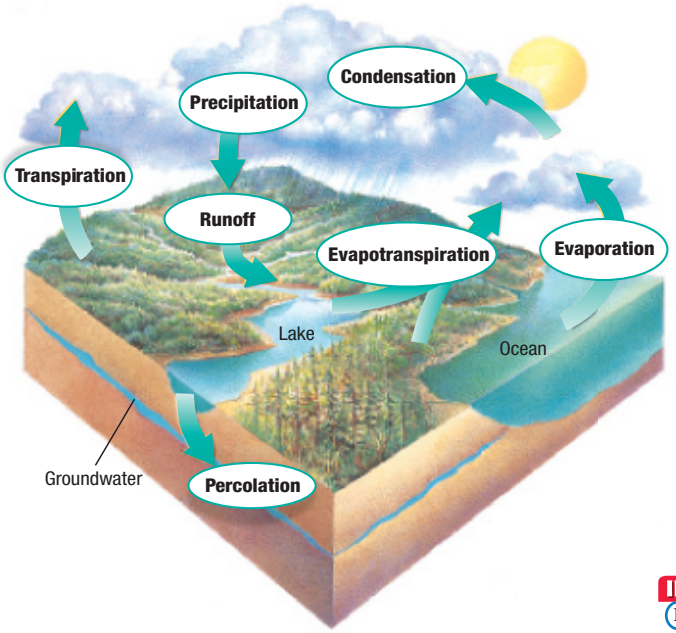


Figure 2 Evapotranspiration, condensation, and precipitation make up a continuous process called the *water cycle*.

THINK central
INTERACT ONLINE
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Water Budget

The continuous cycle of evapotranspiration, condensation, and precipitation establishes Earth's *water budget*. A financial budget is a statement of expected income—money coming in—and expenses—money going out. In Earth's water budget, precipitation is the income. Evapotranspiration and runoff are the expenses. The water budget of Earth as a whole is balanced because the amount of precipitation is equal to the amount of evapotranspiration and runoff. However, the water budget of a particular area, called the *local water budget*, usually is not balanced.

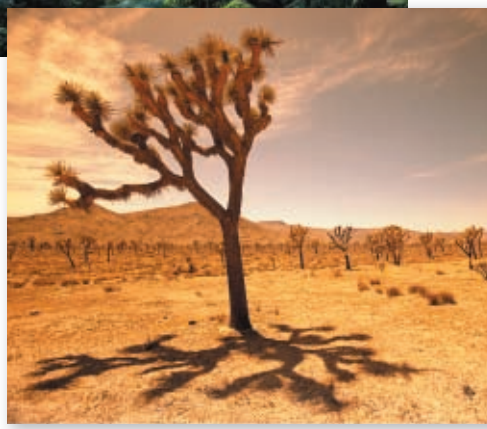


Figure 3 Tropical rain forests, such as the one in Queensland, Australia (top photo), receive large amounts of rainfall annually. Deserts, such as the Mojave Desert in California (bottom photo), receive small amounts of rainfall each year.

Factors That Affect the Water Budget

Factors that affect the local water budget include temperature, vegetation, wind, and the amount of rainfall. When precipitation exceeds evapotranspiration and runoff in an area, the result is moist soil and possible flooding. When evapotranspiration exceeds precipitation, the soil becomes dry and irrigation may be necessary. Vegetation reduces runoff in an area but increases evapotranspiration. Wind increases the rate of evapotranspiration.

The factors that affect the local water budget vary geographically. For example, the Mojave Desert in California receives much less precipitation than do the tropical rain forests of Queensland, Australia, as **Figure 3** shows.

In most areas of Earth, the local water budget also changes with the seasons. In general, cooler temperatures slow the rate of evapotranspiration. During the warmer months, evapotranspiration increases. As a result, streams generally transport more water in cooler months than they do in warmer months.

Quick Lab — Modeling the Water Cycle

35 min

Procedure

1. Place a **short glass** inside a **large plastic mixing bowl.** Add **cold water** to the mixing bowl until about three-fourths of the glass is covered with water. Make sure to keep the inside of the glass dry.
2. Add drops of **food coloring** (red, blue, or green) to the water in the bowl until the water has a strong color.
3. Now, add about 1 cup of dry **soil** to the water,and stir gently until the water is muddy as well as colored.
4. Cover the bowl tightly with a **piece of plastic wrap** secured to the bowl with a **rubber band,** and place a **coin or stone** in the middle of the plastic wrap above the glass.
5. Set the bowl in the sun or under a **heat lamp** for 30 minutes to several hours. Then, observe the water that has collected in the glass.

Analysis

1. What are the processes that have taken place to allow water to collect in the glass?
2. Why is the water in the glass not muddy?
3. Is the water in the glass colored? What does this say about pollutants in water systems and the water cycle?

Figure 4 Waste from a paper mill has polluted the Qingai River in China.

Water Use

On average, each person in the United States uses about 95,000 L (20,890.5 gal) of water each year. Water is used for bathing, washing clothes and dishes, watering lawns, carrying away wastes, and drinking. Agriculture and industry also use large amounts of water. As the population of the United States increases, so does the demand for water.

About 90% of the water used by cities and industry is returned to rivers or to the oceans as wastewater. Some of this wastewater contains harmful materials, such as toxic chemicals and metals, as shown in **Figure 4.** These toxic materials can pollute rivers and can harm plants and animals in the water.

Conservation of Water

While Earth holds a lot of water, only a small percentage of that water is fresh water that can be used by humans. Scientists have identified two ways to ensure that enough fresh water is available today and in the future. One way is through conservation, or the wise use of water resources. Individuals can conserve water by limiting their water use as much as possible. Governments can help conserve water by enforcing conservation laws and antipollution laws that prohibit the dumping of waste into bodies of water.

A second way to protect the water supply is to find alternative methods of obtaining fresh water. One such method is called **desalination,** which is the process of removing salt from ocean water. However, this method is expensive and is impractical for supplying water to large populations. Currently, the best way of maintaining an adequate supply of fresh water is the wise use and conservation of the fresh water that is now available.

Academic Vocabulary

method (METH uhd) a way of doing something

desalination a process of removing salt from ocean water

Section 1 Review

Key Ideas

1. **List** two ways in which water reaches the oceans.
2. **Outline** the major stages of the water cycle.
3. **Explain** the difference between condensation and precipitation.
4. **Explain** why most local water budgets are not balanced.
5. **Describe** how vegetation and rainfall affect the local water budget.
6. **List** two ways to ensure the continued supply of fresh water.

Critical Thinking

7. **Applying Concepts** Describe five ways that you can conserve water at home.
8. **Analyzing Processes** Why are the oceans the location of most evaporation and precipitation?

Concept Mapping

9. Use the following terms to create a concept map: *water cycle, evaporation, transpiration, evapotranspiration, condensation, precipitation,* and *water budget*.

SECTION 2

Stream Erosion

Key Ideas	Key Terms		Why It Matters
❯ Summarize how a river develops. ❯ Describe the parts of a river system. ❯ Explain factors that affect the erosive ability of a river. ❯ Describe how erosive factors affect the development of a river channel.	**tributary** **watershed** **stream load** **discharge**	**gradient** **meander** **braided stream**	Rivers change course over time. Because they also often form political boundaries, such change can cause problems for people living on both sides of the river.

A river system begins to form when precipitation exceeds evapotranspiration in a given area. Excess water then moves downslope as runoff. As runoff moves across the land surface, it erodes rock and soil and eventually may form a narrow ditch, called a *gully*. Eventually, the processes of precipitation and erosion form a fully developed valley with a permanent stream.

Parts of a River System

A river system is made up of a main stream and **tributaries,** which are all of the feeder streams that flow into the main stream. The land from which water runs off into these streams is called a **watershed.** The ridges or elevated regions that separate watersheds are called *divides*. A river system is shown in **Figure 1.**

The relatively narrow depression that a stream follows as it flows downhill is called its *channel*. The edges of a stream channel that are above water level are called the stream's *banks*. The part of the stream channel that is below the water level is called the stream's *bed*. A stream channel gradually becomes wider and deeper as it erodes its banks and bed.

tributary a stream that flows into a lake or into a larger stream

watershed the area of land that is drained by a river system

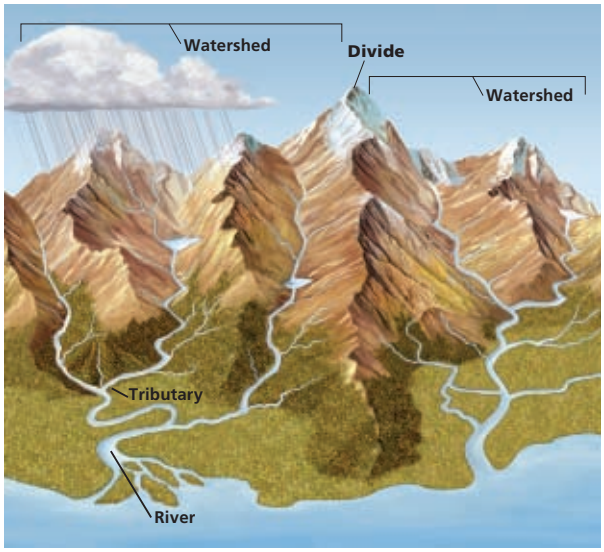


Figure 1 The tributaries that run into this river are fed by runoff from surrounding land. All of the land that drains into a single river makes up the watershed of the river.

Channel Erosion

River systems change continuously because of erosion. In the process of *headward erosion*, channels lengthen and branch out at their upper ends, where runoff enters the streams. Erosion of the slopes in a watershed can also extend a river system and can add to the area of the watershed. In the process known as *stream piracy*, a stream from one watershed is "captured" by a stream from another watershed that has a higher rate of erosion. The captured stream then drains into the river system that has done the capturing.

stream load the materials other than the water that are carried by a stream

discharge the volume of water that flows within a given time

gradient the change in elevation over a given distance

Stream Load

A stream transports soil, loose rock fragments, and dissolved minerals as it flows downhill. The materials carried by a stream are called the **stream load.** Stream load takes three forms: suspended load, bed load, and dissolved load. The *suspended load* consists of particles of fine sand and silt. The speed, or rate of downstream travel, of the water keeps these particles suspended, so they do not sink to the stream bed. The *bed load* is made up of larger, coarser materials, such as coarse sand, gravel, and pebbles. This material moves by sliding and jumping along the bed. The *dissolved load* is mineral matter transported in liquid solution.

Math Skills

Water Discharge of a River River channels can carry an enormous volume of water. The water that rivers discharge can be calculated by using the following equation:

discharge = *speed of the water* x *cross-sectional area of the river channel*

In cubic meters per second (m^3/s), what is the discharge of water carried by a river that moves 1.5 m/s through a cross-sectional area of 520 m^2?

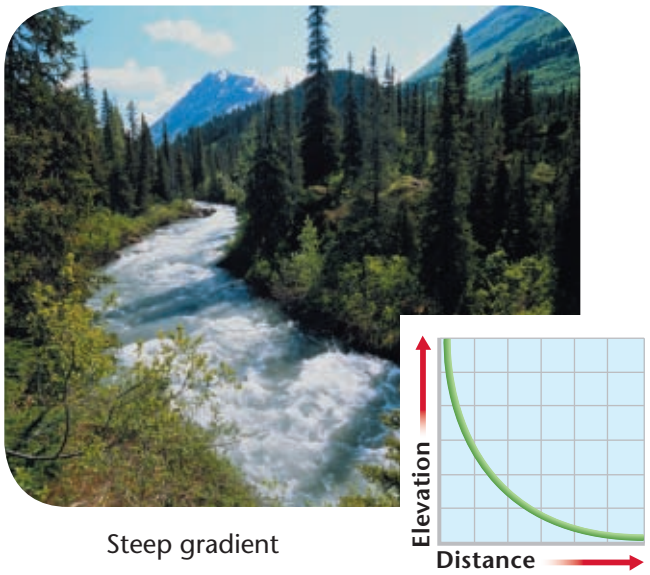
Stream Discharge

The volume of water moved by a stream in a given time period is the stream's **discharge.** The faster a stream flows, the higher its discharge and the greater the load that the stream can carry. Thus, a swift stream carries more sediment and larger particles than a slow stream does. A stream's speed also affects how the stream cuts down and widens its channel. Swift streams erode their channels more quickly than slow-moving streams do.

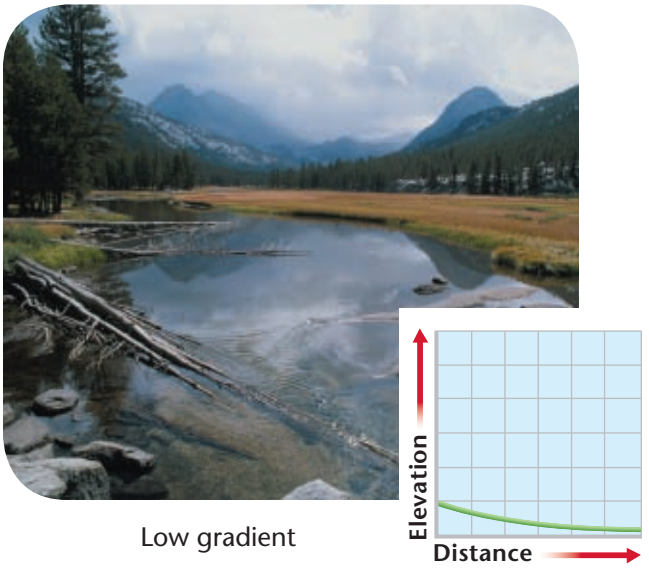
Stream Gradient

The speed of a stream depends mainly on gradient. **Gradient** is the change in elevation of a stream over a given horizontal distance. In other words, gradient is the steepness of the stream's slope. Near the *headwaters*, or the beginning of a stream, the gradient generally is steep. This area of the stream has a high rate of flow, which causes rapid channel erosion. As the stream nears its *mouth*, where the stream enters a larger body of water, its gradient often becomes flatter. As a result, the river's speed and erosive power decrease. The stream channel eventually is eroded to a nearly flat gradient by the time the stream channel reaches the sea. Streams with different gradients are shown in **Figure 2.**

Figure 2 Streams that have steep gradients, such as the stream on the left, have a higher speed than streams that have low gradients, such as the stream on the right, do.



Steep gradient



Low gradient

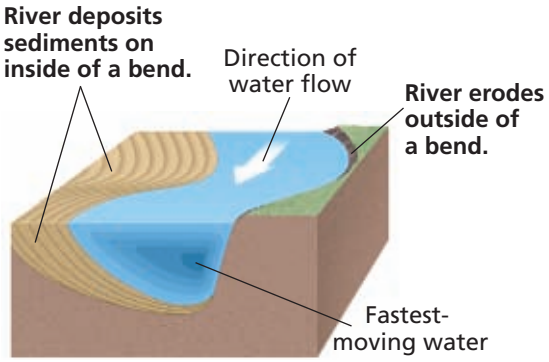


Figure 3 Decreased speed on the inside of a river's curve leads to the deposition of sediment, as this photo of a river in the Banff National Park in Alberta, Canada, shows.

Development of River Channels

As the stream's load, discharge, and gradient decrease, the erosive power of the stream decreases, which influences the development of the stream's channel. Over time, as the channel erodes, it becomes wider and deeper. When the stream becomes longer and wider, it is called a *river*.

Meandering Channels

As a river develops, it may form curves and bends. A river that has a low gradient tends to have more bends than a river that has a steep gradient does. A winding pattern of wide curves, called **meanders,** develops because as the gradient decreases, the speed of the water decreases. When the speed of the water decreases, the river is less able to erode down into its bed. As the water flows through the channel, more energy is directed against the banks, which causes erosion of the banks.

meander one of the bends, twists, or curves in a low-gradient stream or river

When a river rounds a bend, the speed of the water on the outside of the curve increases. The fast-moving water on the outside of a river bend erodes the outer bank of that bend. However, on the inside of the curve, the speed of the water decreases. This decrease in speed leads to the formation of a *bar* of deposited sediment, such as sand or gravel, as shown in **Figure 3.**

As this process continues, the curve enlarges while further sediment deposition takes place on the opposite bank, where the water is moving more slowly. Meanders can become so curved that they almost form a loop, separated by only a narrow neck of land. When the river cuts across this neck, the meander can become isolated from the river, and an *oxbow lake* forms.

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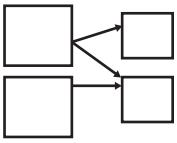
Code: **HQX1314**

Reading Check **How would you describe the gradient of a river that has meanders?**

Figure 4 Braided streams, such as the Chisana River in Alaska, divide into multiple channels.

READING TOOLBOX

Cause-and-Effect Map
Make a cause-and-effect map that is similar to the one you made at the beginning of this chapter. Label the effects "meandering channels" and "braided streams." Then fill in the map with causes of meandering channels and braided streams. Add details about the causes and effects.



Academic Vocabulary
available (uh VAYL uh buhl) able to be used

braided stream a stream or river that is composed of multiple channels that divide and rejoin around sediment bars

Braided Streams

Most rivers are single channels. However, under certain conditions, the presence of sediment bars between a river's banks can divide the flow of the river into multiple channels. A stream or river that is composed of multiple channels that divide and rejoin around sediment bars is called a **braided stream.** Braided streams are a direct result of a high gradient and a large sediment load, particularly when a high percentage of the load is composed of coarse sand and gravel. The bars form on the channel floor when the river is unable to move all of the available load.

Although braided streams, such as those in **Figure 4,** look very different from meandering channels, they can cause just as much erosion. The channel location shifts constantly such that bars between channels erode and new bars form. Sometimes, a single river can change from a braided stream to a meandering stream as the gradient and discharge change.

Section 2 Review

Key Ideas

1. **Summarize** how a river develops.
2. **Describe** the parts of a river system.
3. **Explain** the processes of headward erosion and stream piracy.
4. **List** the three types of stream load.
5. **Explain** how stream discharge and gradient affect the erosive ability of a river.
6. **Describe** the factors that control whether a river is braided or meandering.
7. **Summarize** the process that forms an oxbow lake.

Critical Thinking

8. **Predicting Consequences** If geologic forces were to cause an uplift of the land surface, what would the effect on stream channel erosion be?
9. **Analyzing Processes** Explain how the speed of a stream affects the suspended load.

Concept Mapping

10. Use the following terms to create a concept map: *braided channels, stream load, suspended load, dissolved load, bed load, meanders, stream gradient,* and *headwaters.*

SECTION 3

Stream Deposition

Key Ideas	Key Terms	Why It Matters
❯ Explain the two types of stream deposition. ❯ Describe one advantage and one disadvantage of living in a floodplain. ❯ Identify three methods of flood control. ❯ Describe the life cycle of a lake.	**delta** **alluvial fan** **floodplain**	Building a dam involves risks, but *not* building a dam also has risks. An understanding of floodplains is critical for making good decisions about whether or not to build a dam.

The total load that a stream can carry is greatest when a large volume of water is flowing swiftly. When the speed of the water decreases, the ability of the stream to carry its load decreases. As a result, part of the stream load is deposited as sediment.

Deltas and Alluvial Fans

A stream may deposit sediment on land or in water. For example, the load carried by a stream can be deposited when the stream reaches an ocean or a lake. As a stream empties into a large body of water, the speed of the stream decreases sharply. The load is usually deposited at the mouth of the stream in a triangular shape. A triangular-shaped deposit that forms where the mouth of a stream enters a larger body of water is called a **delta.** The exact shape and size of a delta are determined by waves, tides, offshore depths, and the sediment load of the stream.

When a stream descends a steep slope and reaches a flat plain, the speed of the stream suddenly decreases. As a result, the stream deposits some of its load on the level plain at the base of the slope. A fan-shaped deposit called an **alluvial fan** forms on land, and its tip points upstream. In arid and semiarid regions, temporary streams commonly form alluvial fans. Alluvial fans differ from deltas in that alluvial fans form on land instead of being deposited in water. This difference is shown in **Figure 1.**

delta a fan-shaped mass of rock material deposited at the mouth of a stream

alluvial fan a fan-shaped mass of rock material deposited by a stream when the slope of the land decreases sharply

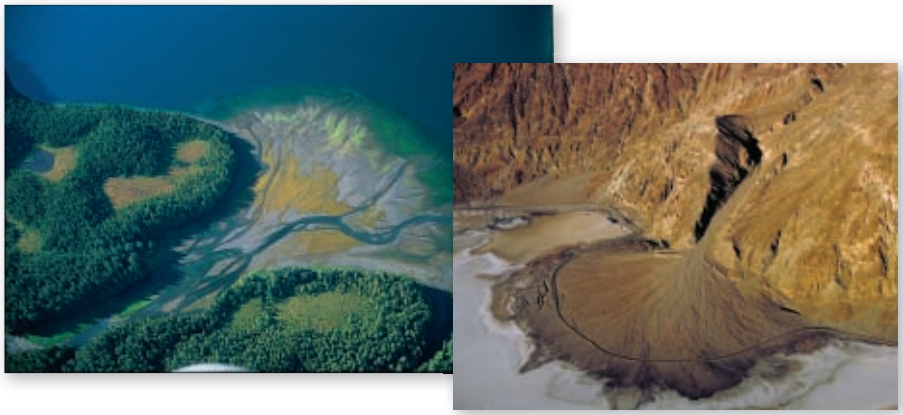


Figure 1 A delta, such as this one in Alaska's Prince William Sound (above), forms when a stream deposits sediment into another body of water. An alluvial fan, such as this one in California's Death Valley (right), forms when a stream deposits sediment on land.

Figure 2 Raised on stilts, houses in the Tonle Sap Floodplain in Cambodia stay dry during frequent flooding.

Floodplains

The volume of water in nearly all streams varies depending on the amount of rainfall and snowmelt in the watershed. A dramatic increase in volume can cause a stream to overflow its banks and to wash over the valley floor. The part of the valley floor that may be covered with water during a flood is called a **floodplain.**

Natural Levees

When a stream overflows its banks and spreads out over the floodplain, the stream loses speed and deposits its coarser sediment load along the banks of the channel. The accumulation of these deposits along the banks eventually produces raised banks, called *natural levees*.

Finer Flood Sediments

Not all of the load deposited by a stream in a flood will form levees. Finer sediments are carried farther out into the floodplain by the flood waters and are deposited there. A series of floods produces a thick layer of fine sediment, which becomes a source of rich floodplain soils. Swampy areas are common on floodplains because drainage is usually poor in the area between the levees and the outer walls of the valley. Despite the hazards of periodic flooding, people choose to live on floodplains, as shown in **Figure 2.** Floodplains provide convenient access to the river for shipping, fishing, and transportation. The rich soils, which are good for farming, also draw people to live on floodplains.

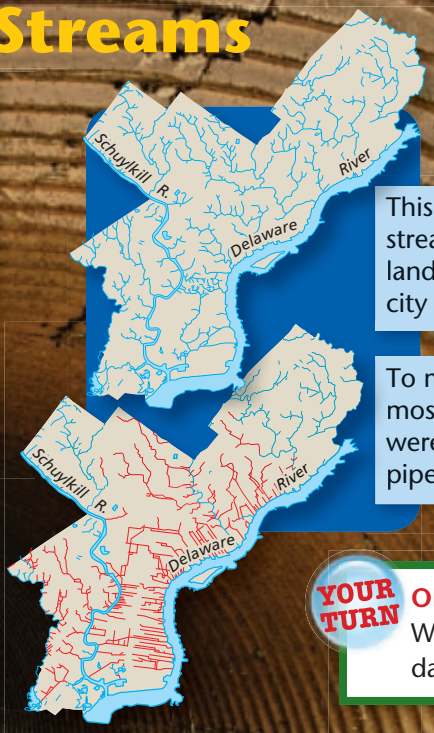
floodplain an area along a river that forms from sediments deposited when the river overflows its banks

Why It Matters

Uncovering Lost Streams

EYE ON THE ENVIRONMENT

Waterways in urban areas have been dramatically altered over time. Buried streams flow unseen in pipes beneath many North American cities. Some cities, however, are working to re-establish or "daylight" lost streams because of the environmental benefits. Daylighting returns a buried stream to its place above ground. Reestablished streams provide new habitats and beautify neighborhoods.



This map shows the many streams that flowed over the land that is now covered by the city of Philadelphia.

To make way for development, most of Philadelphia's streams were rerouted in underground pipes (shown in red).

YOUR TURN

ONLINE RESEARCH
What is Philadelphia doing to daylight its streams?

Quick Lab Soil Erosion

40 min

Procedure

1. Fill a **23 cm × 33 cm pan** about half full with **moist, fine sand.**
2. Place the pan in a **sink** so that one end of the pan is resting on a **brick** and is under the water faucet.
3. Position an **additional pan or container** such that it catches any sand and water that flow out of the first pan.
4. Slowly open the faucet until a gentle trickle of water falls onto the sand in the raised end of the pan. Let the water run for 15 to 20 s.
5. Turn off the water, and draw the pattern of water flow over the sand in your notebook.
6. Press the sand back into place, and carefully smooth the surface by using a **ruler.** Repeat steps 4 and 5 three more times. Each time, increase the rate of water flow slightly without splashing the sand.

Analysis

1. Describe how the rate of water flow affects erosion.
2. How does the rate of water flow affect gullies?
3. How could erosion on a real hillside be reduced without changing the rate of water flow?
4. How does the shape of a river bend change as water flows?

Human Impacts on Flooding

Human activity can contribute to the size and number of floods in many areas. Vegetation, such as trees and grass, protects the ground surface from erosion by taking in much of the water that would otherwise run off. Where this natural ground cover is removed, water can flow more freely across the surface. As a result, the likelihood of flooding increases. Logging and the clearing of land for agriculture or housing development can increase the volume and speed of runoff, which leads to more frequent flooding. Natural events, such as forest fires, can also increase the likelihood of flooding.

READING TOOLBOX

Suffixes

Add the words *accumulation, transportation,* and *conservation* to the suffix table you started at the beginning of this chapter. Remember to write the verb that each *-ation* word came from, as well as the verb's definition.

Flood Control

Indirect methods of flood control include forest and soil conservation measures that prevent excess runoff during periods of heavy rainfall. More-direct methods include the building of artificial structures that redirect the flow of water.

The most common method of direct flood control is the building of *dams*. The artificial lakes that form behind dams act as reservoirs for excess runoff. The stored water can be used to generate electricity, supply fresh water, and irrigate farmland. Another direct method of flood control is the building of *artificial levees*. However, artificial levees must be protected against erosion by the river. As **Figure 3** shows, when artificial levees break, flooding and property damage can result. Permanent overflow channels, or *floodways,* can also help prevent flooding. When the volume of water in a river increases, floodways carry away excess water and keep the river from overflowing.

Reading Check **Describe two ways that floods can be controlled.**

Figure 3 This levee near New Orleans broke as a result of Hurricane Katrina, allowing the Mississippi River through.

Precipitation collects in a depression and forms a lake.

A lake loses its water as the water drains away or evaporates.

As water is lost, the lake basin may eventually become dry land.

Figure 4 Compared to rivers, lakes are short lived, and some lakes may eventually dry up.

SCILINKS.
www.scilinks.org
Topic: Flooding and Society
Code: **HQX0585**
Topic: Stream Deposition
Code: **HQX1457**

The Life Cycle of Lakes

Not all streams flow from the land to the ocean. Sometimes, water from streams collects in a depression in the land and forms a lake. Most lakes are located at high latitudes and in mountainous areas. Most of the water in lakes comes from precipitation and the melting of ice and snow. Springs, rivers, and runoff coming directly from the land are also sources of lake water.

Most lakes are relatively short lived in geologic terms. Many lakes eventually disappear because too much of their water drains away or evaporates, as shown in **Figure 4.** A common cause of excess drainage is an outflowing stream that erodes its bed below the level of a lake basin. Lakes may also lose water if the climate becomes drier and evaporation exceeds precipitation.

Lake basins may also disappear if they fill with sediments. Streams that feed a lake deposit sediments in the lake. Sediments also are carried into the lake by water that runs off the land but does not enter a stream. Most of these sediments are deposited near the shore. These sediments build up over time, which creates new shorelines and gradually fills in the lake. Organic deposits from vegetation also may accumulate in the bottom of a shallow lake. As these deposits grow denser, a bog or swamp may form. The lake basin may eventually become dry land.

Academic Vocabulary

exceed (ek SEED) to be more than

Section 3 Review

Key Ideas

1. **Identify** the differences between a delta and an alluvial fan.
2. **Explain** the differences between the deposition of sediment in deltas and alluvial fans with the deposition of sediment on a floodplain.
3. **Describe** the advantages and disadvantages of living in a floodplain.
4. **Summarize** how human activities can affect the size and number of floods.
5. **Identify** three methods of flood control.
6. **Explain** why lakes are usually short lived.

Critical Thinking

7. **Analyzing Ideas** Why are spring floods common in rivers where the headwaters are in an area of cold, snowy winters?
8. **Making Inferences** If you were picking a material to make an artificial levee, what major characteristic would you look for? Explain your answer.

Concept Mapping

9. Use the following terms to create a concept map: *stream deposition, delta, alluvial fan, floodplain, natural levee, dam, artificial levee,* and *lake.*

Why It Matters

The Three Gorges Dam

SCIENCE & SOCIETY

How would you feel if you had to relocate your home because a new dam that is under construction will lead to the flooding of your town? Millions of people in China were affected by the construction of the Three Gorges Dam across the Yangtze River, the largest hydroelectric dam ever built. This enormous project was started with the intention of providing needed electric power and preventing flooding. However, the project also raises many social and environmental issues.

Dam construction creates a massive lake upstream that covers old valleys, such as this one. Pollution build-up in the new lake causes problems for nearby ecosystems and residents.

The new lake also covered cities, towns, and historical sites. About 1.3 million people had to relocate their homes.

The dam can provide millions of people with needed power and minimize power shortages in China's growing cities.

YOUR TURN

ONLINE RESEARCH

Use the Internet to research the arguments for and against construction of the Three Gorges Dam.

WRITING IN SCIENCE

Would you have supported or opposed the construction of the dam? Write one page explaining your argument.

Inquiry **Lab**

45 min

Sediments and Water

Running water erodes some types of soil more easily than it erodes others. How rapidly a soil erodes depends on how well the soil holds water. In this lab, you will determine the erosive effect of water on various types of sediment.

What You'll Do

- **Measure** the amount of water that sediment can hold.
- **Identify** the properties that affect how sediment interacts with water.

What You'll Need

graduated cylinder, 100 mL
grease pencil
juice containers, 12 oz (2)
metric ruler
nail, large
pan, 23 cm × 33 cm × 5 cm or larger
sand, dry and coarse
silt, dry
stopwatch or clock with second hand
water

Safety

Ask a Question

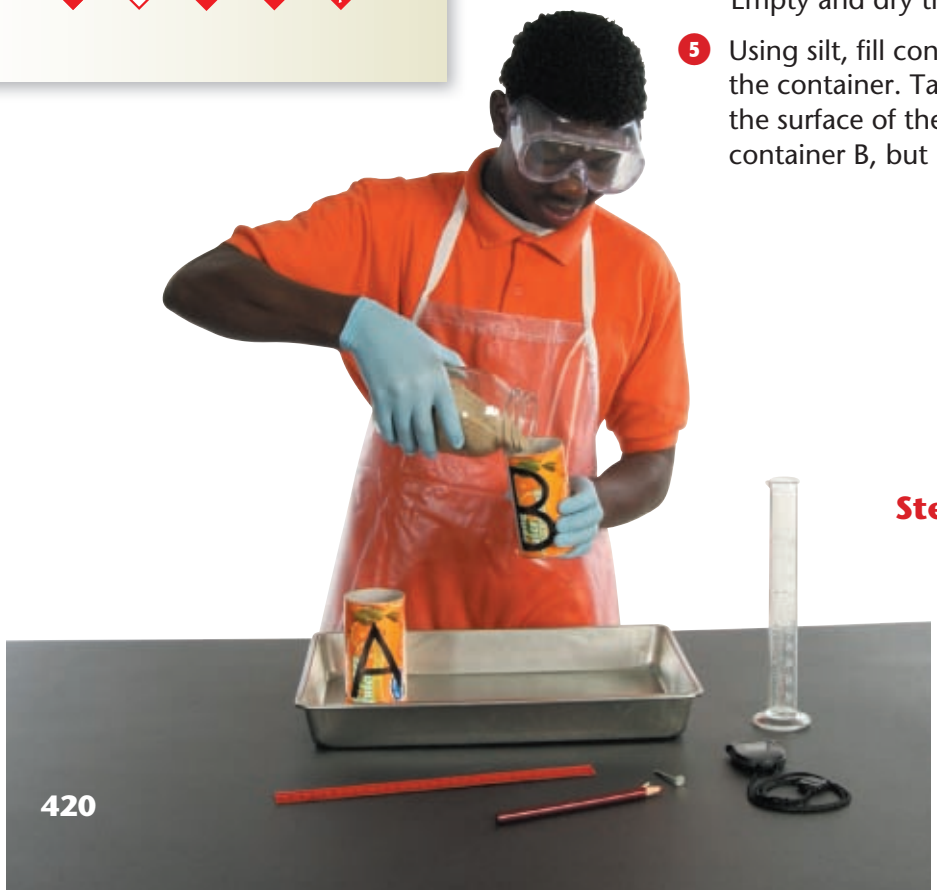
1. Which type of soil would hold more water: sandy soil or silty soil? Which soil would water flow through faster and therefore would erode more rapidly: sandy soil or silty soil?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the questions above.

Test the Hypothesis

3. Use a graduated cylinder to pour 300 mL of water into each of two juice containers.
4. Place the containers on a flat surface. Using a grease pencil, draw a line around the inside of the containers to mark the height of the water. Label one container "A" and the other "B." Empty and dry the containers.
5. Using silt, fill container A up to the line drawn inside the container. Tap the container gently to even out the surface of the sediment. Repeat this step for container B, but use sand.



Step 5

6. Fill the graduated cylinder with 100 mL of water. Slowly pour the water into container A. Stop every few seconds to allow the soil to absorb the water. Continue pouring until a thin film of water forms on the surface of the sediment. If more than 100 mL of water is needed, refill the graduated cylinder and continue this step.
7. Record the volume of water poured into the container.
8. Using container B, repeat steps 6 and 7. Record your observations.
9. Use a metric ruler to measure 1 cm above the surface of the sediment in each container. Using the grease pencil, draw a line to mark this height on the inside of each container. Pour water from the graduated cylinder into containers A and B until the water reaches the 1 cm mark.
10. Poke a nail through the very bottom of the side of container A. Place the container inside the pan. At the same time, start recording the time by using a stopwatch and pull the nail out of the container.
11. Observe the water level, and record the amount of time that the water takes to drop to the sediment surface.
12. Using container B, repeat steps 10 and 11. Record your observations.

Step 8

Step 12

Analyze the Results

1. **Analyzing Results** In step 8, which type of sediment held more water?
2. **Analyzing Results** Which type of sediment was the water able to flow through faster?
3. **Summarizing Results** What properties of the sediment do you think affected how the water flowed through the sediment? Explain your answer.

Draw Conclusions

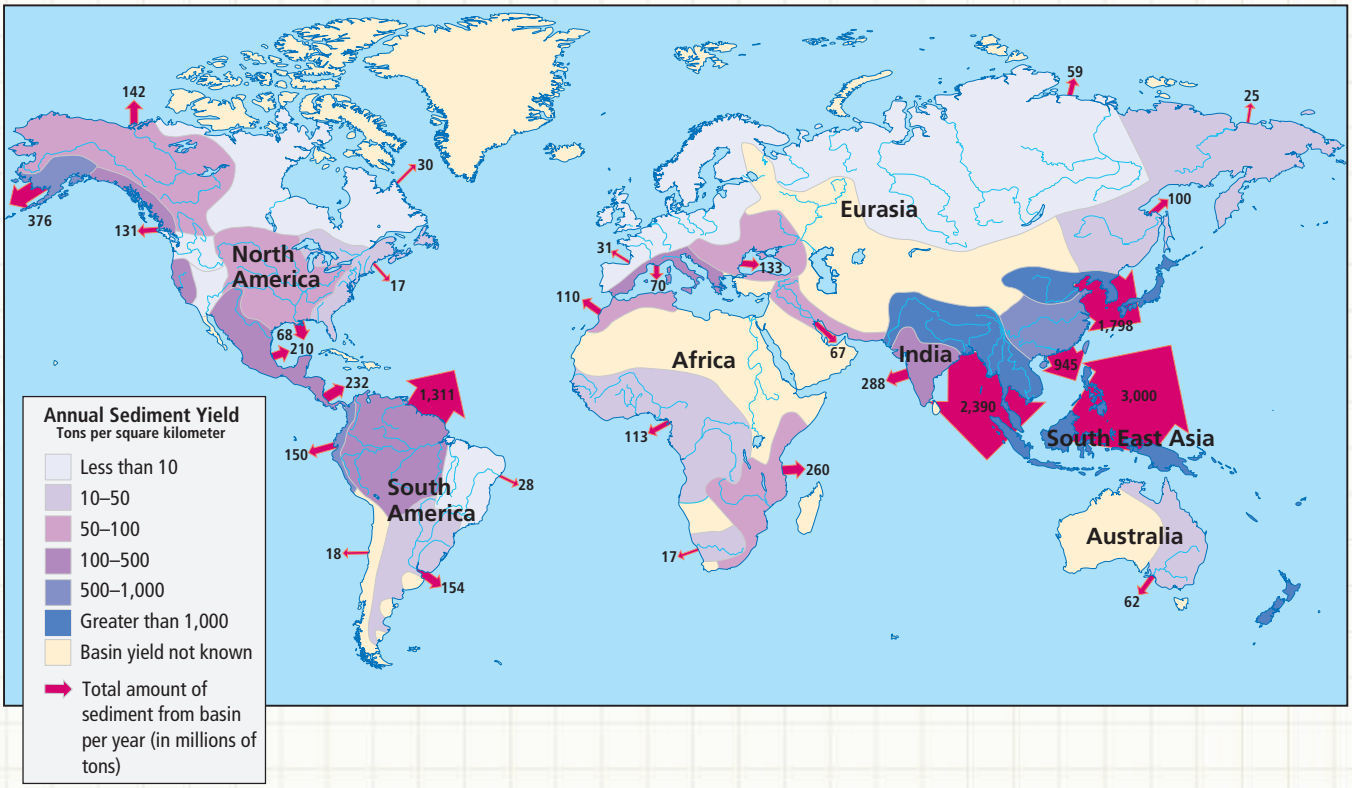
4. **Analyzing Results** On the basis of your answers to the questions above, which would water erode more quickly: an area of silt or an area of sand? Explain your answer.
5. **Drawing Conclusions** In which sediment do you think a deep stream channel is most likely to form? In which sediment is a meandering stream likely to form? Explain your answers.

Extension

Applying Conclusions Describe three ways to make slopes covered with soil more resistant to erosion.

MAPS in Action

World Watershed Sediment Yield



Map Skills Activity

This map shows the world's watersheds and identifies the sediment yield of each watershed basin in tons per square kilometer and the total amount of sediment that each basin dumps into the ocean in millions of tons per year. Use the map to answer the questions below.

1. **Using a Key** Which area has the highest total annual sediment yield from one basin?
2. **Using a Key** What is the range of the annual sediment yield in tons per square kilometer for the United States, excluding Alaska?
3. **Analyzing Data** What is the total amount of sediment that basins in South America yield per year?
4. **Analyzing Relationships** Areas that have high relief (where the range of elevations is great) tend to have higher sediment yields than do areas of low relief (where the topography is flatter). Which area would you conclude has higher relief: Africa or South East Asia? Explain your answer.
5. **Making Comparisons** Both the Amazon basin, which is in northern South America, and the India basin have an annual sediment yield range of 100 to 500 tons per square kilometer. However, the total amount of sediment per year from the Amazon basin is 1,311 million tons, while the total amount of sediment per year from the India basin is 288 million tons. Explain why these two basins differ so significantly in their total sediment yield per year.

Chapter 15

Summary

THINK central SUPER SUMMARY Keyword: HQXRVSS

Key Ideas	Key Terms

Section 1 The Water Cycle

- The water cycle involves the processes of evapotranspiration, condensation, and precipitation.
- A region's water budget is affected by temperature, vegetation, wind, and the amount of rainfall.
- Water can be conserved by individuals limiting water use and by governments enforcing conservation laws and antipollution laws.

water cycle, p. 407
evapotranspiration, p. 408
condensation, p. 408
precipitation, p. 408
desalination, p. 410

Section 2 Stream Erosion

- A river develops over time, through the processes of precipitation and erosion.
- A river system consists of a main stream and tributaries.
- The erosive ability of a river is affected by stream load, stream discharge, and stream gradient.
- Erosive factors, such as gradient and discharge, can affect the development of a river channel, forming meanders and braided streams.

tributary, p. 411
watershed, p. 411
stream load, p. 412
discharge, p. 412
gradient, p. 412
meander, p. 413
braided stream, p. 414

Section 3 Stream Deposition

- Two types of stream deposition are deltas, which form in water, and alluvial fans, which form on land.
- Living in a floodplain has advantages, such as access to a river and rich soil, but the risk of flooding is a disadvantage.
- Three methods of flood control include forest and soil conservation, dams, and artificial levees.
- Over time, a lake may lose its water or fill with sediment and become dry land.

delta, p. 415
alluvial fan, p. 415
floodplain, p. 416

Chapter 15 Review

1. **Venn Diagram** Make a Venn diagram with two circles. Label one circle "Meandering channel" and the other circle "Braided stream." In the area where the circles overlap, write shared characteristics. In each of the other areas, write characteristics that are unique to each type of river.

READING TOOLBOX

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *water cycle*
3. *gradient*
4. *evapotranspiration*
5. *floodplain*

For each pair of terms, explain how the meanings of the terms differ.

6. *condensation* and *precipitation*
7. *watershed* and *tributary*
8. *stream load* and *discharge*
9. *delta* and *alluvial fan*

UNDERSTANDING KEY IDEAS

10. The change of water vapor into liquid water is called
    a. runoff.
    b. desalination.
    c. evaporation.
    d. condensation.
11. In a water budget, the income is precipitation and the expense is
    a. evapotranspiration and runoff.
    b. condensation and saltation.
    c. erosion and conservation.
    d. conservation and sedimentation.
12. The land area from which water runs off into a stream is called a
    a. tributary. **c.** divide.
    b. watershed. **d.** gully.
13. Tributaries branch out and lengthen as a river system develops by
    a. headward erosion.
    b. condensation.
    c. saltation.
    d. runoff.
14. The stream load that includes gravel and large rocks is the
    a. suspended load. **c.** dissolved load.
    b. runoff load. **d.** bed load.
15. A fan-shaped formation that develops when a stream deposits its sediment at the base of a steep slope is called a(n)
    a. delta.
    b. meander.
    c. oxbow lake.
    d. alluvial fan.
16. The part of a valley floor that may be covered during a flood is the
    a. floodway.
    b. floodplain.
    c. meander.
    d. artificial levee.
17. One way to control floods indirectly is through
    a. soil conservation.
    b. dams.
    c. floodways.
    d. artificial levees.

SHORT ANSWER

18. How does a local water budget differ from the water budget of the whole Earth?
19. How is reducing the pollution in streams and groundwater linked to water conservation?
20. Describe how bank erosion can cause a river to meander.
21. Why do most rivers that have a large sediment load also have a fast flow of water?
22. Describe how lakes fill with sediment.
23. What is the difference between direct and indirect methods of flood control?

CRITICAL THINKING

24. Evaluating Ideas How would Earth's water cycle be affected if a significant percentage of the sun's rays were blocked by dust or other contaminants in the atmosphere?

25. Making Comparisons Use an atlas to determine the geographic location of Kolkata, India, and Stockholm, Sweden. How might the local water budgets of these two cities differ? Explain your answer.

26. Making Inferences The Colorado River is usually grayish brown as it flows through the Grand Canyon. What causes this color?

27. Making Predictions What do you think would happen to cities in the southwestern United States if rivers in that area could not be dammed?

CONCEPT MAPPING

28. Use the following terms to create a concept map: *water vapor, condensation, precipitation, channel, stream load, bar, alluvial fan, delta, divides, watersheds, tributaries, floodplains, dams,* and *artificial levees.*

MATH SKILLS

Math Skills

29. Making Calculations If a river is 3,705 km long from its headwaters to its delta and the average speed of its water is 250 cm/s, use the equation *time* = *distance* ÷ *speed* to determine how many days a water molecule takes to make the trip.

30. Using Equations You wish to examine the annual water budget for the state of Colorado. If p = total precipitation, e = total evapotranspiration, r = total stream runoff, and g = total water soaking into the ground, what equation will allow you to determine whether Colorado experiences a net loss or net gain of water over the course of a year?

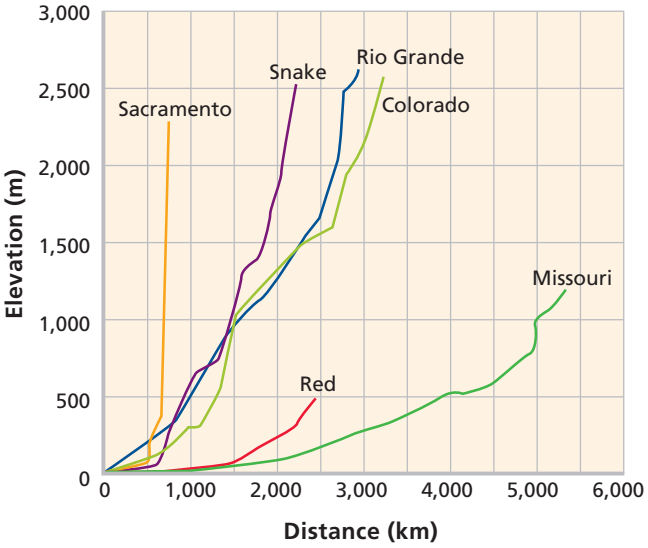
WRITING SKILLS

31. Writing Persuasively Write a persuasive essay of at least 300 words that suggests ways in which your community can conserve water and reduce water pollution.

32. Communicating Main Ideas Discuss the dangers and advantages of living in a river floodplain. Outline the options for adapting to living in a river floodplain.

INTERPRETING GRAPHICS

The graph below shows the gradients of several rivers of the United States. Use the graph to answer the questions that follow.



33. Which river has the shallowest average gradient over its entire course?

34. Which river has the steepest average gradient over its entire course?

35. Based only on gradient, how would the speed of the Snake River compare with the speed of the Missouri River?

36. Which end of each line on the graph represents the headwaters of the river system? Explain your answer.

Chapter 15 Standardized Test Prep

Understanding Concepts

Directions (1–4): For each question, write on a separate sheet of paper the letter of the correct answer.

1. Condensation is often triggered as water vapor rising in the atmosphere
- **A.** cools.
- **B.** warms.
- **C.** contracts.
- **D.** breaks apart.

2. The continuous movement of water from the ocean, to the atmosphere, to the land, and back to the ocean is
- **F.** condensation.
- **G.** the water cycle.
- **H.** precipitation.
- **I.** evapotranspiration.

3. Which of the following drains a watershed?
- **A.** floodplains
- **B.** a recharge zone
- **C.** an artesian spring
- **D.** streams and tributaries

4. Like rivers, lakes have life cycles. Most lakes have short life cycles and eventually disappear. Which of the following conditions may cause a lake to disappear?
- **F.** when evaporation exceeds precipitation
- **G.** when precipitation exceeds evaporation
- **H.** when sediments are removed from the lake
- **I.** when a local water budget is balanced

Directions (5–8): For each question, write a short response.

5. What is the term for a volume of water that is moved by a stream during a given amount of time?

6. The gradient of a river is defined as a change in what over a given distance?

7. Streams are said to have varying loads. What makes up a stream's load?

8. Desalination removes what naturally occurring compound from ocean water?

Reading Skills

Directions (9–11): Read the passage below. Then, answer the questions.

The Mississippi Delta

In the Mississippi River Delta, long-legged birds step lightly through the marsh and hunt fish or frogs for breakfast. Hundreds of species of plants and animals start another day in this fragile ecosystem. This delta ecosystem, like many other ecosystems, is in danger of being destroyed.

The threat to the Mississippi River Delta ecosystem comes from efforts to make the river more useful. Large parts of the river bottom have been dredged to deepen the river for ship traffic. Underwater channels were built to control flooding. What no one realized was that the sediments that once formed new land now pass through the channels and flow out into the ocean. Those river sediments had once replaced the land that was lost every year to erosion. Without them, the river could no longer replace land lost to erosion. So, the Mississippi River Delta began shrinking. By 1995, more than half of the wetlands were already gone—swept out to sea by waves along the Lousiana coast.

9. Based on the passage, which of the following statements about the Mississippi River is true?
- **A.** The Mississippi River never floods.
- **B.** The Mississippi River is not wide enough for ships to travel on it.
- **C.** The Mississippi River's delicate ecosystem is in danger of being lost.
- **D.** The Mississippi River is disappearing.

10. Based on the passage, which of the following statements is true?
- **F.** By 1995, more than half of the Mississippi River was gone.
- **G.** Underwater channels may control flooding.
- **H.** Channels help form new land.
- **I.** Sediment cannot replace lost land.

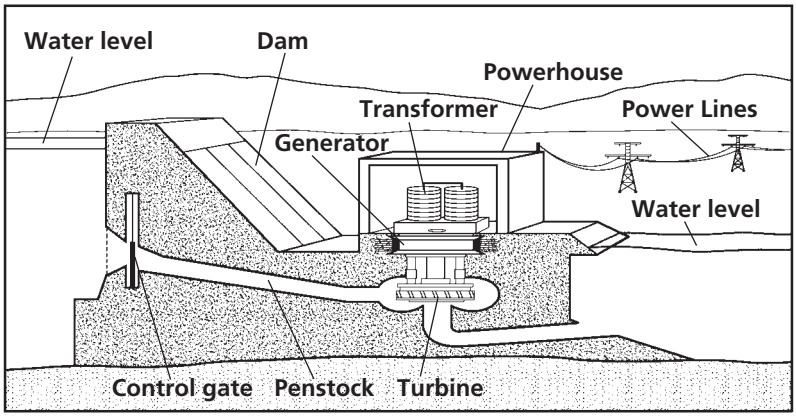
11. The passage mentions that damage to the ecosystem came from efforts to make the river more useful. For who or what was the river being made more useful?

Interpreting Graphics

Directions (12–15): For each question below, record the correct answer on a separate sheet of paper.

The diagram below shows how a hydroelectric power plant works. Use this diagram to answer questions 12 and 13.

Hydroelectric Power Plant



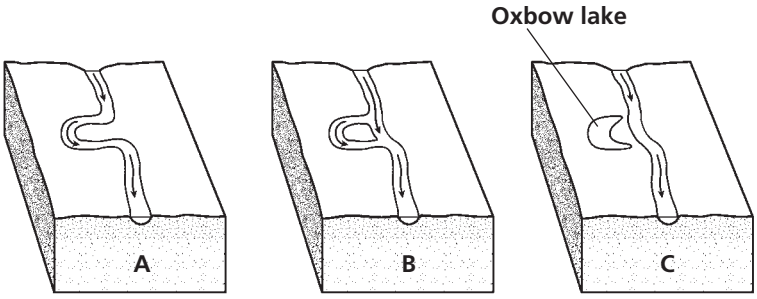
12. Hydroelectric dams are used to generate electricity for human use. As water rushes past the machinery inside, an electric current is generated. What does water rush past to turn the generator, which produces the current?

A. a transformer
B. the control gate
C. an intake
D. a turbine

13. Look at the diagram above. What direction does the water flow? What makes the water flow in this direction?

The graphic below shows the formation of an oxbow lake. Use this graphic to answer questions 14 and 15.

Formation of an Oxbow Lake



14. What is the term for the wide curves whose development causes the formation of oxbow lakes?

F. wanders
G. meanders
H. bows
I. loops

15. How does the speed at which the water flows contribute to the process of forming an oxbow lake?

Test Tip

If you are permitted to, draw a line through each incorrect answer choice as you eliminate it.