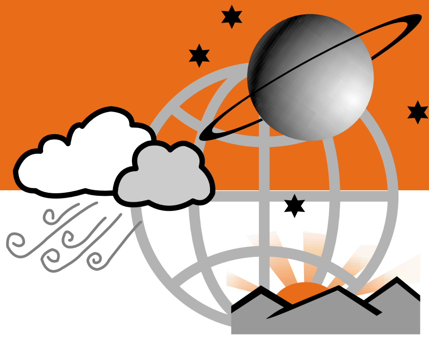


Chapter 12

River Systems

WHAT IS A RIVER SYSTEM?

Rivers have always been important to us. The trade routes of native Americans as well as the routes of exploration by Europeans followed rivers to reach the interior of North America. Travel by water was easier than travel by land, especially where vegetation was thick, and travelers had to carry food and supplies. Before roads were built, rivers were the avenues of travel, trade, and communications. The earliest European settlements were along the coastline, where there was access to shipping and manufactured goods. From coastal cities, settlement and commerce followed waterways to the interior. Today, highways, railroads, and air routes have replaced streams as our primary arteries for travel, settlement, and commerce. Rivers and lakes still carry some commerce while they supply freshwater and serve as recreational areas.

A system is a collection of parts that contribute to a single function. A river system, or **stream system**, consists of all the streams that drain a particular geographic area. A **stream** is any flowing water, such as a brook, river, or even an ocean current. The function of a river is to transport water and sediments from a specific land area to an ocean or a lake. Water

Figure 12-1 This braided stream in Alaska is transporting so much sediment that the stream spreads over its own sediment load.

and sediments have potential energy at the beginning of their journey. The amount of energy depends on how high they are above the end, or mouth, of the stream. As water and sediment flow downhill, potential energy is changed to kinetic energy. At the end of the stream where water flows into the calm water of a lake or ocean, potential energy has decreased because water and sediments are at their lowest elevation. Kinetic energy decreases as these materials stop moving. For these materials, the transporting function of the stream system has been accomplished. Figure 12-1 shows a stream that is transporting a large load of sediment.

Watershed

The geographic area drained by a particular river or stream is its **watershed**, or drainage basin. All the rain, snow, and other precipitation that falls into the watershed and does not escape by infiltration, evaporation, or transpiration must exit the watershed through its principal river, stream, or other body of water. (Sometimes a lake or an ocean rather than a river is used to define a watershed.) **Drainage divides** separate one watershed from the next. These are high ridges from which water drains in opposite directions. You can identify watershed boundaries and trace the perimeter of

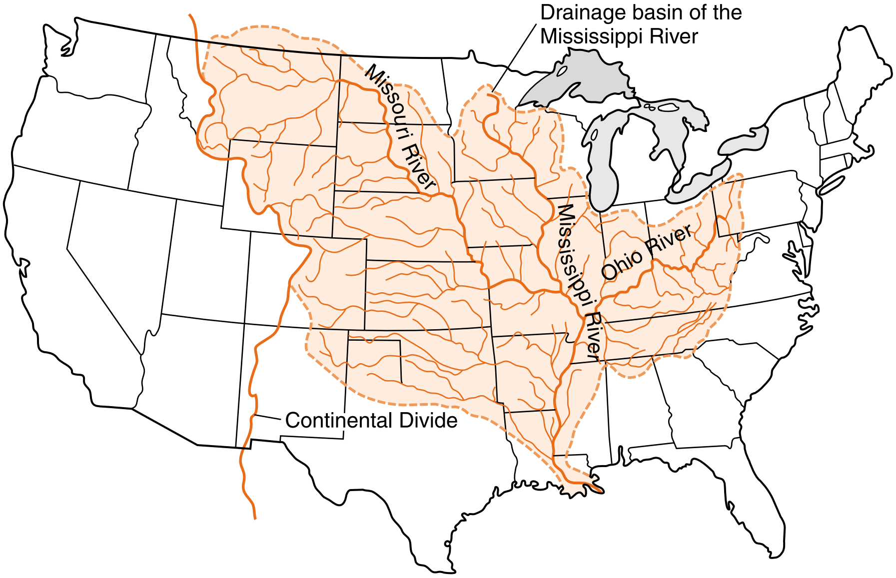


Figure 12-2 The Mississippi River and its tributaries drain about half of the surface area of the United States.

a watershed by drawing a line that separates all the streams draining into one watershed, from streams that flow into adjacent watersheds. Drainage divides never cross streams or rivers. At its lowest level, the drainage divide of a particular stream ends only where the stream flows into another body of water. Figure 12-2 shows the Mississippi River's watershed.

Watersheds are important because they show the region drained by a particular stream system. Figure 12-3 shows a small watershed in Utah. Communities that draw water from a nearby stream or river depend on rain and snow that falls within the watershed. The availability of water for such a community depends only on the amount and the quality of

Figure 12-3 The water that flows to the lowest point in this closed basin in Utah evaporates during dry summer weather.

precipitation in the watershed upstream from the municipal intake. When a water-soluble form of pollution is released into the environment, it flows downhill, and is carried into the nearest stream. As smaller streams join larger streams, the pollution affects only downstream locations in the watershed. Like water pollution, flooding is also confined to a particular watershed.

Most of the precipitation that falls over the continents falls on solid ground. If this water does not infiltrate the ground or evaporate, it must flow downhill under the influence of gravity as **overland flow**, or **runoff**. The amount of runoff depends on the slope of the land, the permeability of the surface, and the amount of precipitation. The steeper the slope, the greater the runoff. More water runs off a hard surface, such as pavement, than off a permeable surface, such as soil. The presence of grasses and shrubs in the soil also decreases runoff because they absorb water. The greater the amount of precipitation, rain or snow, the greater the runoff. Overland flow continues until the water reaches a stream.

Names such as brook or creek are often used to label small streams that flow into larger streams such as rivers. A stream that flows into another larger stream is called a **tributary**. In large watersheds, small tributaries join to form larger tributaries which themselves may be a tributary of even larger streams. The Bedrock Geology of New York State map in the *Earth Science Reference Tables* shows some of the major rivers of New York State.

ACTIVITY 12-1 DRAINAGE OF THE SCHOOL GROUNDS

Make a map of your school grounds to determine how water drains off different parts of the property. On the map, identify potential sources of water pollution and show what parts of the grounds would most likely be affected by these sources of pollution. Also show where runoff could cause erosion problems and suggest ways to prevent these problems.

Features of Streams

As most streams flow from their source to their mouth, the *slope*, or *gradient*, of the stream decreases and the shape of the valley becomes broader. Streams that form steep, V-shaped valleys in mountain areas emerge into regions where the land is less steep. Here the valleys become broad with floodplains. (See Figure 12-4.)

FLOODPLAIN Most of the time, the stream is confined to a relatively narrow and winding path along the bottom of the valley. But in times of flood, streams overflow their banks and spread over a flood plain. A **floodplain** is a flat region next to a stream or river that may be covered by water in times of flood. Floodplains are valued as agricultural land because sediments brought by periodic floods enrich the soil with important minerals and nutrients for plant growth. Figure 12-5 shows a stream as it changes through time from a narrow, steep-sided valley to a broad valley in which the stream can wander over its floodplain.

The occasional flooding of agricultural land is considered an acceptable risk. However, when local governments allow

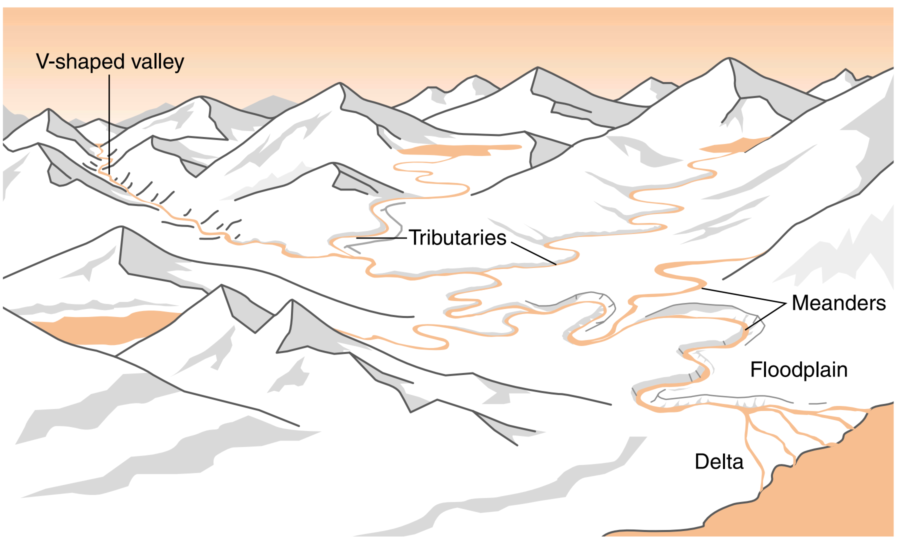


Figure 12-4 As a stream flows out of mountains and tributaries add water, V- shaped valleys change to broader valleys with flood plains. Deltas are deposited where the stream slows upon entering a lake or ocean.

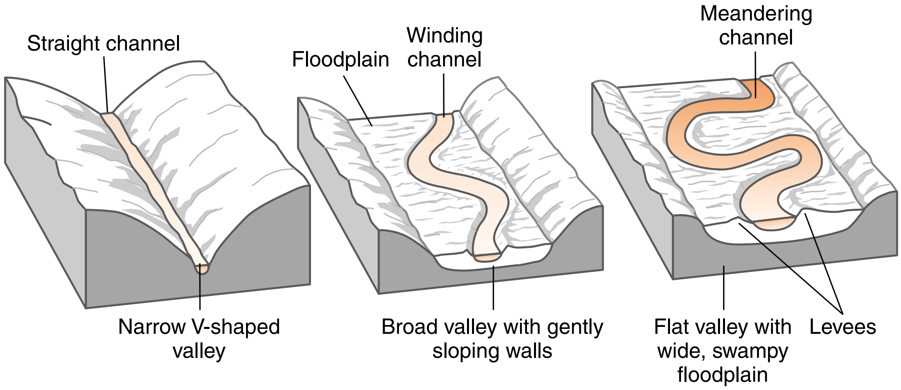


Figure 12-5 Through time, rivers erode their valleys changing from a narrow, steep sided, V–shaped valley to a valley with a broad U–shaped bottom and a floodplain.

houses and other buildings to be constructed on floodplains, periodic flooding can cause considerable losses. This is why zoning laws are important to protect citizens from property loss and even loss of life in times of flood.

DELTA As most rivers continue downstream, they empty into the calm water of a lake or ocean. With loss of velocity, the water also loses its ability to transport sediment. Deposition often forms a delta at the end of the stream. A **delta** is a region at the end (mouth) of a stream or river that consists of sediments deposited as the velocity of the stream decreases. The name *delta* comes from the Greek letter Δ (delta). Sometimes delta deposits have this shape. Look again at Figure 12-4, which shows stream features including V-shaped valleys, tributaries, a floodplain, and a delta.

MEANDERS As a stream flows over relatively flat land, its path develops curves called **meanders**. Builders of irrigation canals have discovered that when the channel has a soft streambed and little slope, the path of the canal tends to meander. Even when the path of the water is initially straight, meanders develop, through time, unless the banks are lined with a hard material such as concrete. The curves of a meandering stream are the natural shape of steams and rivers that have a low gradient and flow over a broad valley.

Once meanders have formed, they do not remain stationary through time. If you could see a greatly speeded-up view

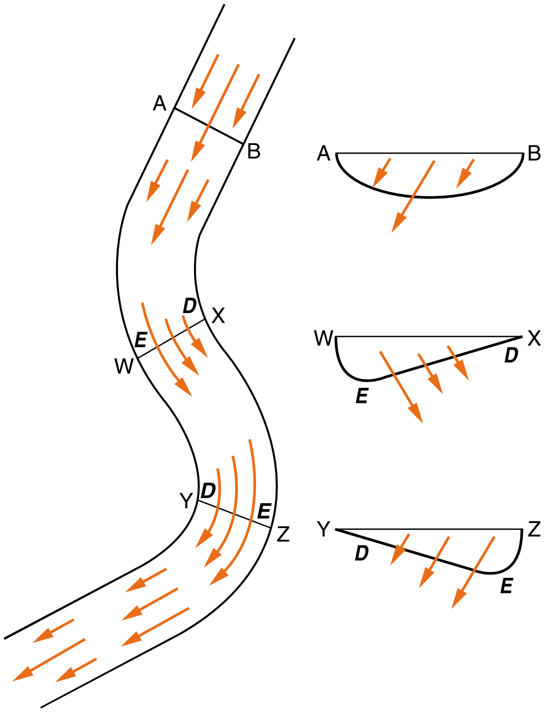


Figure 12-6 In a straight section of a stream (A–B) the fastest current is at the center of the stream. But in a meander (W–X and Y–Z) the fastest current swings to the outside of the curve. Erosion (***E***) occurs on the outsides of meanders where the current is fastest and deposition (***D***) takes place on the inside of meanders where water flows slowest. Erosion and deposition cause streams to change their paths through time.

of a meandering stream over many years, the meanders would shift like the slithering motion of a snake. How do they do this? Streams change their course as a result of erosion and deposition. Erosion occurs where the water flows fastest and deposition takes place where the water slows down.

Figure 12-6 is a diagram of a section of a stream. The length of the arrows indicate the water's speed at various places in the stream. Where the stream is straight, the fastest current is near the center. But when the water flows through a meander, the fastest current swings to the outside of the curve. Inertia is responsible for the changing position of the fastest water. This is the same force you feel when you quickly round a corner in a car. Everyone in the car feels a force to one side of the car. In the same way, the water in the stream travels in a straight path until water building up at the side of the stream forces the water to turn.

This pattern of water velocity with continuing erosion and deposition change the course of a meandering stream. For ex-

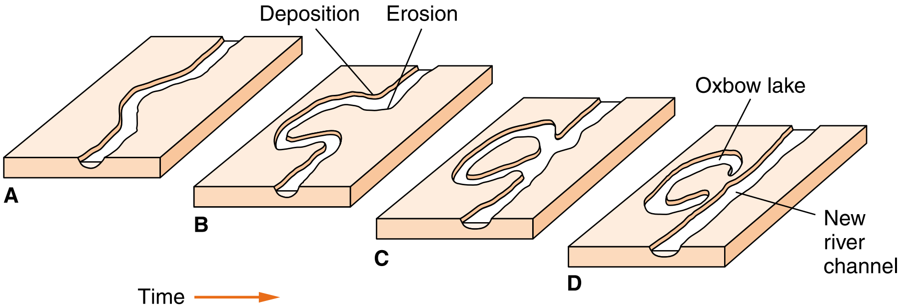


Figure 12-7 Meanders form where the stream gradient is low and there is a broad floodplain. Diagram A shows the stream starting to form a meander. In B erosion and deposition are starting to cut through the meander. The cutoff is complete in C. Deposition along the edge of the river leaves the meander isolated as an oxbow lake in D.

ample, in Figure 12-6 along profile A–B, the shape of the stream is not changing. Therefore erosion and deposition are in equilibrium. But at a meander, the faster current swings to the outside of the curve and causes erosion. On the inside of the bend where the water is slow, deposition dominates. If a stream has a low gradient, a straight stream will tend to form meanders and then cut off its meanders as shown in Figure 12-7.

LEVEES Streams in broad valleys sometimes flood and leave deposits of sand and silt on the land bordering and parallel to the streams. These ridges are called levees. In the area of New Orleans, Louisiana, the first homes were built on the natural levees along the Mississippi River. These areas were the highest and driest locations in the flat delta region. The land away from the riverbanks is often low and swampy. These natural levees are often used as foundation for tall, human-made levees, which are built to keep the river confined to its channel in times of flood.

However, when people alter natural systems, untended results often occur. Tall levees may force the river to deposit its sediment load in the river channel. In some locations, the Mississippi River is now higher than the surrounding land. This increases the danger of flooding, and may require the artificial levees to be built higher and higher through time.

ACTIVITY 12-2 MODELING A STREAM SYSTEM

Materials: stream table, fine sand, or coarse silt

Observe and list characteristics and common features of streams that develop on a stream table. How does the path of the stream change through time? Where do erosion and deposition occur?

HOW DO WE MEASURE STREAMS?

Two aspects of streams that scientists measure are size and velocity. Size is more than just the length of the stream. Several factors affect the velocity of a stream.

Stream Size

The size of a stream can be measured in several ways. One measure is the area of its watershed. In general, the larger the drainage basin, the larger the stream. However, some locations receive more precipitation than others. In a dry region, a large watershed may only supply water to streams that are dry most of the year. Some watersheds receive so little rain and snow that none of the water in the stream flows out of the watershed. Streams in these areas run into bodies of water that lose their water by evaporation, or the stream water may seep into the ground before the stream reaches its lowest level.

Stream size is more often measured by finding discharge. **Discharge** is the amount of water flowing in a stream past a particular place in a specified time. For example, a small stream may have discharge of a fraction of a cubic meter per second. However, the Amazon River in South America, which has the greatest discharge of any river on Earth, discharges about 200,000 m^3 of freshwater into the Atlantic Ocean each second.

To measure the discharge of a stream, you need to measure the area of its cross section at a particular location, then multiply that value by the velocity of the stream. You can determine the area of the cross section by multiplying the average depth of the stream by its width at that point. Area is in units such as square meters. Velocity can be expressed in meters per second. The product of these values is therefore cubic meters per second. The formula below shows how to calculate discharge volume:

$$\text{Discharge} = \text{area of cross section} \times \text{stream velocity}$$

ACTIVITY 12-3 MEASURING STREAM DISCHARGE

Materials: Device to measure distance, watch, or timer

Use the method in the text above to measure the discharge of a stream near your school or home. Can you devise a different method to find the discharge in order to verify the first value that you obtained?

Streams respond differently to rainfall depending on their sizes. As you can see in Figure 12-8, large streams are slower to respond than small streams. This is because the water in a large drainage basin has a greater distance to flow before it reaches the major stream. Streams in smaller watersheds

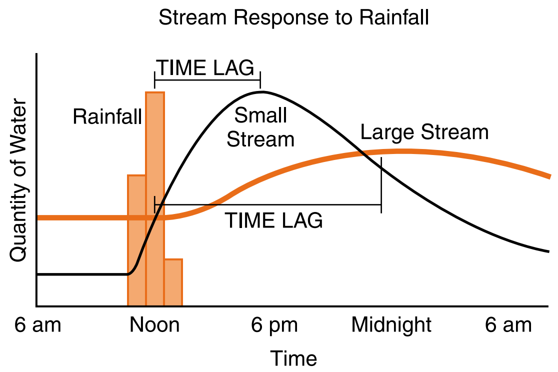


Figure 12-8 Maximum stream discharge occurs after the time of maximum rainfall. In general, small streams respond more quickly than do larger streams because small streams have smaller watersheds.

generally respond quickly because the precipitation does not flow far to reach a small stream.

Stream Velocity

How quickly water flows in a stream is a function of three factors: shape of the stream channel, gradient (slope), and volume of water. If the stream channel is straight and smooth, water can flow quickly. But if the stream is flowing through large rocks, the rocks slow the water as it bounces from rock to rock. Many mountain streams are filled with coarse sediment such as large cobbles and boulders that slow the stream velocity.

The gradient of a stream also determines how quickly water moves. The force of gravity maintains flow of water. Other factors being equal, the steeper a stream channel, the faster water will flow.

The third factor is the volume of water flowing in a stream. As the quantity of water in a stream increases, so does the pull of gravity. If the discharge of a stream increases, usually the weight of water increases more quickly than the resistance of the stream channel. Most streams are steepest at the beginning of the stream and the gradient decreases as they flow downstream. But many rivers flow faster as they move downstream because the increase in the volume of the stream dominates over the reduction in slope.

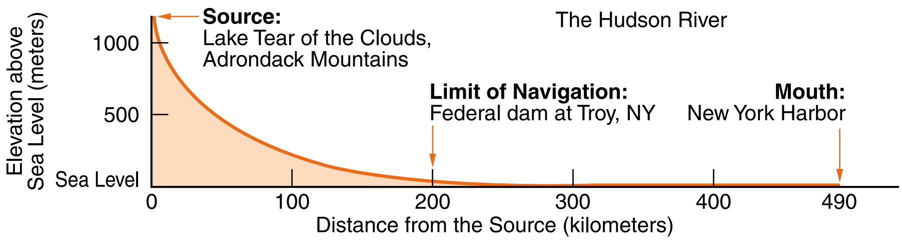
Figure 12-9 shows profiles along the length of the Hudson River and the Colorado River. The concave shape of these profiles is typical of many streams: steeper near their sources than they are near the end of the stream.

ACTIVITY OR DEMONSTRATION 12-4

WATER VELOCITY

Materials: Stream table or running water and tilted trough to represent a stream bed, meter stick, stop watch, or timer

Determine the influence of gradient and stream discharge on stream velocity. Measure the velocity of the water as the gradient and the discharge are changed. Use your data to explain how gradient and discharge affect stream velocity.



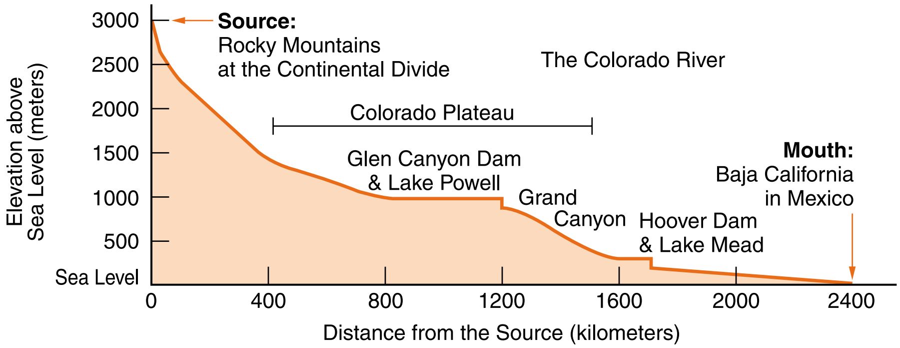


Figure 12-9 The longitudinal profiles of both rivers are concave as their slope decreases downstream. The double concave shape of the Colorado River profile is evidence of uplift of the Colorado Plateau.

You can measure the speed of a stream by selecting a relatively straight section of a small stream. You will need a device to measure distance, such as a meter stick, a timing device such as a watch with a second hand, or a stopwatch, and an object to float downstream. (In case there is wind, it may be best to use an object that floats, but is mostly submerged.) Measure the length of the stream section in units such as meters. Then place the floating object in the water above the measured section and time how long it takes for the object to float through the measured distance. The stream velocity can be calculated using the formula.

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$

SAMPLE PROBLEM

Problem Two students stand 53 m apart along a straight portion of a small stream. One student places a floating marker in the stream and immediately begins timing it with a stopwatch. If the marker passes the second student in 15 s, what is the average velocity of this section of the stream?

Solution

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{53\ \text{m}}{5\ \text{s}}$$

$$= 3.5\ \text{m/s}$$

Notice that the solution is expressed to two digits, as are the values of time and distance.

Practice

1. A floating marker takes 21 s to travel 88 m along a straight portion of a stream. What is the average velocity of this section of the stream?
2. The average velocity of a stream is 2.7 m/s. How far will a marker travel in 16 s?

ACTIVITY 12-5 MEASURING STREAM VELOCITY

Materials: Device to measure distance, watch, or timer

Use the method in the text above to measure the velocity of a small stream near your school or home. (**Note:** This should be done under adult supervision to ensure safety.)

WHAT IS A DRAINAGE PATTERN?

Streams seek the lowest path as they move downhill, and they tend to erode their beds in places where the ground is weak. Therefore, both topography and geologic structure influence the path streams follow through an area, which we call the **drainage pattern**. By looking at a map view of a stream, you can often infer the underlying bedrock structures. Figure 12-10 shows the relationship between stream pattern and rock structure.

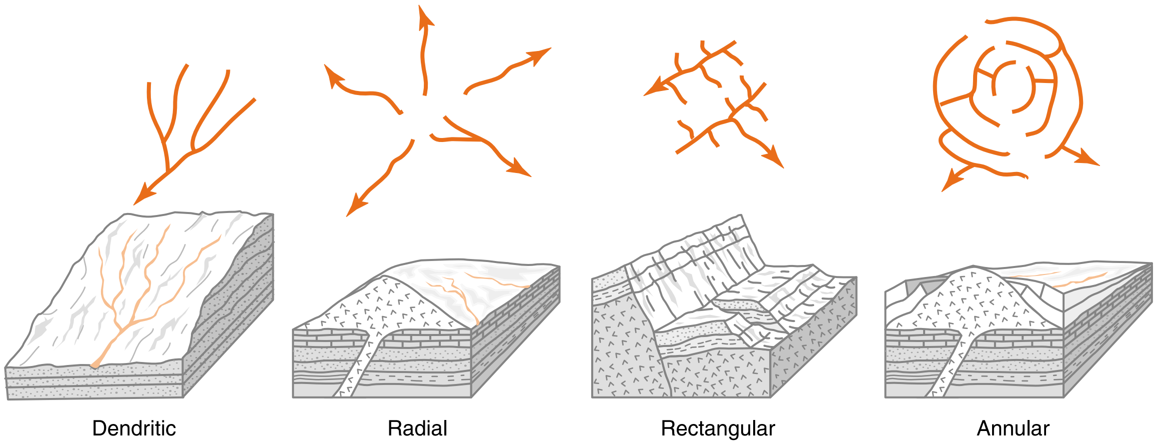


Figure 12-10 Underlying rock features influence the drainage patterns we see on map views of streams. Streams follow low areas, weak rock types, and fractured rocks.

The most common stream pattern is a dendritic drainage. Dendritic streams flow downhill in the same general direction and they join to make larger streams. As a result, they have a branching appearance. This pattern is common where the bedrock is uniform, without faults, folds, or other major structures or zones of weakness to capture the streams. Dendritic drainage is also common where the rock layers are horizontal. Much of the region of western New York State north of the Pennsylvania border has dendritic drainage because rock layers are flat and there are few faults or folds to divert streams.

A region that has prominent parallel and perpendicular faults, repeated folds, or a strong rectangular jointing pattern will display a rectangular drainage pattern. (Joints are cracks in bedrock along which no significant movement has occurred. They may be related to expansion or regional forces acting on bedrock.) Streams seek the lowest areas of folds, fractured rocks along faults, or the weakest surface bedrock locations.

Annular drainage is a pattern of concentric circles that are connected by short radial stream segments. This type of drainage occurs in an eroded dome

A radial drainage pattern resembles the spokes of a wheel. Streams flow away from a high point at the center of the pattern. Radial drainage may develop on a smooth dome or a volcanic cone. The Adirondack Mountain region of New York displays radial drainage, although rock structures such as faults and folds in the Adirondacks alter the regional pattern and may rake radial drainage hard to observe.

The important point is that the underlying rock types and geologic structures influence streams, and that different structural features produce different patterns of drainage.

TERMS TO KNOW

delta	**floodplain**	**stream system**
discharge	**meander**	**tributary**
drainage divide	**overland flow**	**watershed**
drainage pattern	**runoff**	

CHAPTER REVIEW QUESTIONS

1. Why are streams and rivers with the features of their watersheds called systems?

(1) All streams and rivers are the same size.
(2) Streams and rivers form straight channels.
(3) Different parts contribute the same outcome.
(4) The features of one stream system are not found in other stream systems

2. What name is applied to the outside boundaries of a watershed?

(1) stream channel
(2) meander
(3) drainage divide
(4) tributary

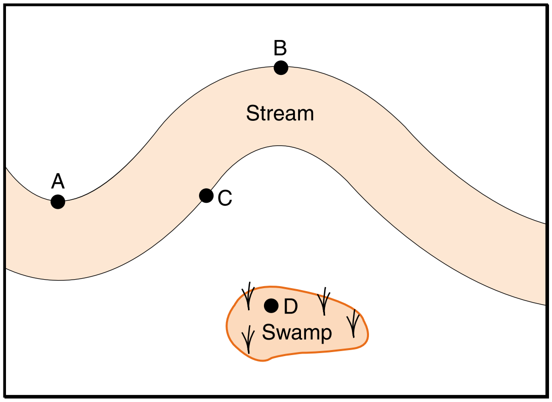
3. Which river is a tributary of the Hudson River?

(1) Delaware River
(2) Susquehanna River
(3) Mohawk River
(4) Genesee River

4. Which condition would cause surface runoff to increase in a particular location?

(1) covering a dirt road with pavement
(2) reducing the gradient of a steep hill
(3) planting grasses and shrubs on a hillside
(4) having a decrease in the annual rainfall

Base your answers to questions 5 and 6 on the diagram below that shows a stream meander.



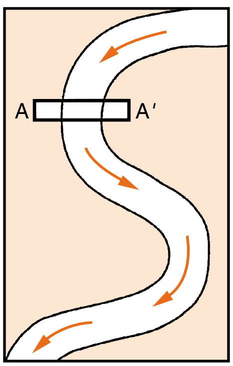
5. At which point is erosion greatest?

(1) A (2) B (3) C (4) D

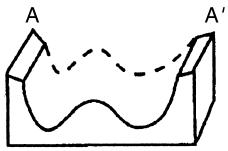
6. Where is deposition most likely to occur?

(1) A (2) B (3) C (4) D

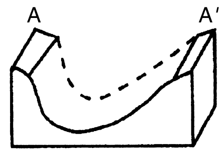
7. The map below shows a meandering stream. A–A′ is the location of a cross section. The arrows show the direction of the stream's flow.



Which diagram below best represents the shape of the river bottom at A–A′?



(1)



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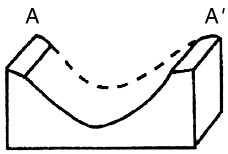

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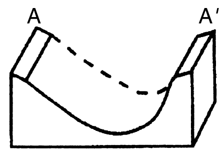


(4)

8. Which location along a river is the most likely place for deposition to dominate over erosion?

(1) the base of a waterfall
(2) the outside of a meander
(3) a section of the river where the gradient is steep
(4) the delta where the river enters the calm water of an ocean

9. Which of the following changes will cause an increase in the amount of erosion in a stream?

(1) an increase in the hardness of bedrock
(2) an increase in the stream discharge
(3) a decrease in the gradient of the stream
(4) a decrease in the average temperature

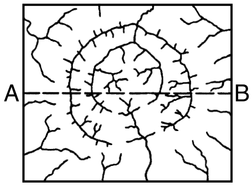
10. Which change would cause an increase in stream velocity?

(1) an increase in the concentration of dissolved solids in the water
(2) an increase in the volume of water flowing in the stream
(3) a decrease in the slope of the stream
(4) a decrease in the temperature of the water

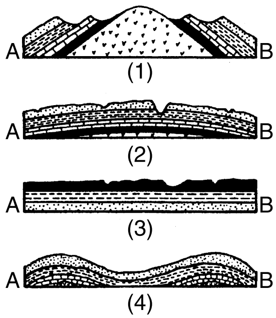
11. Which change would be most likely to increase velocity of water flowing in a river?

(1) a decrease in gradient
(2) a decrease in rainfall
(3) an increase in latitude
(4) an increase in discharge

12. The diagram below is a map showing the stream drainage pattern for an area of Earth's crust.



Which geologic cross section shows the most probable underlying rock structure and surface for this area along line A–B?



13. Which type of stream drainage pattern is most likely in a location where a constant slope dips gently to the north and the bedrock is uniform granite without folding, faulting, or other geologic structures?

(1) a rectangular drainage with streams aligned at right angles
(2) a branching drainage in which streams join as they flow north
(3) streams flowing away from a central location like spokes on a wheel
(4) a drainage pattern that contains many concentric circles connected by short radial stream segments

14. Which of the following factors is *least* likely to influence the drainage pattern of streams in a watershed?

(1) differences in the hardness of bedrock
(2) size of grains in the bedrock
(3) folding of the bedrock
(4) faulting of the bedrock

15. Mercury was found in water wells of a small community. What was the most probable source area of the mercury?

(1) rainfall in a different watershed
(2) a waste dump in a different watershed
(3) a factory upstream in the same watershed
(4) a housing development downstream in the same watershed

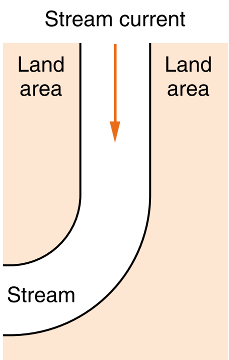
Open-Ended Questions

16. What are the principal functions of any stream system?

17. Why are low areas near rivers better suited for farmland and growing crops than they are for use as home sites.

18. A student decided to measure the speed of a stream by floating apples down a straight section of the stream. Describe the steps the student must take to determine the streams surface rate of movement (speed) by using a stopwatch, a 4-m rope, and several apples. Included the equation for calculating rate.

19. The diagram below shows a stream with a constant flow running through an area where the land around the stream is made of uniform sand and silt. Show the future path of this stream resulting from erosion and deposition as it usually occurs along a meander by drawing two lines to show the future stream banks.



20. Draw a map view of a likely drainage pattern for the landform below.