How Big is the River Really?

Watershed Mapping

Students investigate the concept of a watershed, identify a local river's watershed system and describe the immediate watershed in which their school is located.

Level(s): 6-12

Subject(s): ***Earth Science; Geography***

Virginia SOLs: 6.7 b,c

Objectives:

Students will be able to:

1. define the terms *watershed*, *contour lines, nonpoint source water pollution, sediment, erosion, nutrients, impermeable surface, and/or stream buffer*.

2. use a topographic map to locate waterways, ridge lines and valleys.

3. delineate the boundaries of a local watershed.

4. explain how to prevent nonpoint source pollution of waterways.

Materials:

1. Copies of a topographical map of the stream or river nearest your school – one map per group (to order maps, contact the Virginia Division of Mineral Resources Sales Office in Charlottesville at (434) 951-6341 about their 7.5 –Minute Quadrangle topographic maps, or visit their web site at **www.mme.state.va.us/DMR/PUB/maps.html#7.5**).

2. transparency sheets and pens for each student group

3. one calculator for each group

Estimated Time: 45-90 minutes

Background Information: *Watersheds, Water Pollution and Land Use*, p.4.

Preparation:

1. Obtain copies of topographic maps and other materials. You may want to have the maps laminated.

2. Familiarize yourself with the map, locate the nearest stream to the school and practice delineating its watershed following the instructions below in Activity Procedure #4..

3. You may wish to write some of your own tasks for students to complete while they are familiarizing themselves with the map in Procedure #1 below in addition to the questions below. For example, you might have student measure the distance between various points on the map and convert the answer to feet and/or miles.

4. You may wish to assign the background information for reading before starting this activity.

Activity Procedure:

1. Divide the class into groups of 3-4 students and give each group a topographic map. Give the students the following tasks to familiarize themselves with the map. (Optional: hold a competition to see which group finds each answer first.)

   a. What year was the map created? What year was the map revised?
   b. What is the *contour interval* on the map? (20 feet)
   c. What is the *scale* of the map? (1:24,000)
   d. How many inches on the land does one inch on the map represent? (24,000 in.)
   e. How many feet on the ground does one inch on the map represent? (24,000 in. ÷ 12 = 2,000 ft.)
   f. What do the darker brown contour lines represent? (100-foot intervals)
   g. What does it mean when the contour lines are closer together? (steeper slope)
   h. What point in the quadrangle has the highest *elevation*? What is the elevation?
   i. What point has the lowest elevation? What is the elevation?
   j. Locate your school on the map.
   k. Locate the nearest steam to the school. Does it have a name? If not, what is the name of the first stream it flows into which has a name?

2. Discuss the following from the background information: *watersheds*, *runoff*, *nonpoint source water pollution*, *nutrients*, *sediment*, *impermeable surface*, *stream buffers*.

3. Hand out the transparency sheets and pens. Have the students locate the nearest stream to the school and tape the transparency over it. Have them trace the stream to the nearest larger stream with the pen. Ask how they know which direction the water flows (from higher to lower contours).

4. Next, have the students outline the watershed in which their school is located. The first step is to locate and mark the downstream outlet of the watershed into another body of water. The second step is to locate the high points (hill tops) around the stream and draw an "X" on each one. Then they should connect the dots ("X's") by drawing a line at right angle to the contour lines. The students will want to be sure they are following ridgelines and not valleys. It often helps to find neighboring streams and determine which ridgelines divide them.

Assessment Opportunities:

1. Ask students to explain the meaning of the terms listed in objective #1. Alternatively, you may ask them to match terms and definitions.

2. Give students a portion of a topographic map and have them outline the watershed of a designated stream.

3. Have students explain how to prevent nonpoint source pollution.

Extensions:

1. Have students investigate land use in the watershed they have mapped and indicate land use on the map.

2. Conduct a field trip in the watershed to observe and record land use in the school's watershed (digital cameras may be used to supplement verbal descriptions). If any problems are observed such as erosion, stream bank damage, excess sediment in the stream covering a rocky bottom, excess algal growth, etc. discuss possible causes and solutions.

Adapted from **Georgia Adopt-a-Stream Educator's guide for Grades K-12**, pp 31-35.

Watersheds, Water Pollution and Land Use

What is a watershed?

A watershed is the area of land where all **runoff** drains downhill to the same body of water. Runoff is the rain or melting snow that runs off across the surface of the land instead of sinking into the ground. We can define the watershed we live in as the largest watershed we are a part of, (such as the Chesapeake Bay Watershed), or as of one of the smaller parts of that watershed, such as the watershed of a creek in your backyard.

All parts of a watershed are connected by the runoff that collects at the lowest place in the watershed. If runof carries pollution into one part of the watershed, that pollution is carried dowstream to the lowest place in the watershed.

What is water pollution?

Pollution is something harmful that is added to water or air because of something people do. Water pollution is divided into two types: **point source** pollution and **nonpoint source** pollution. **Point source** pollution is pollution that comes from a well-defined source, such as factory waste or sewage that flows from a pipe into a stream, or gas that leaks from an underground storage tank into the surrounding water table.

Nonpoint source pollution comes from a broad area, such as a rooftop, lawn, field or parking lot. It is washed into surface water by stormwater runoff. For example, rain or melting snow can wash oil and gas off a parking lot and carry it downhill to the nearest stream. **Sediment** and **nutrients** are the two most common types of nonpoint source pollution in the Chesapeake Bay Watershed.

Sediment is soil that is washed away by **erosion**. Erosion occurs when the surface of the ground is not protected by plants. Rain and runoff can loosen and wash away soil when it is not covered with plants. Plants prevent erosion in various ways.

a. Plants protect the soil from the impact of rain (the like an umbrella)
b. Plants **filter** the soil out of runoff by catching soil that is washed away.
c. Plant **roots** hold the soil in place and prevent erosion.

Sediment in water can harm creatures living in the water.

a. Sediment absorbs the sun's energy, making the water too **warm**. Some fish, such as trout, cannot live in warm water. Warm water holds less **oxygen** than cold water.
b. Sediment makes it harder for creatures to see **food**.
c. Sediment clogs the gills of fish and other creatures, making it harder to take in **oxygen**.
d. Sediment can cover the rocks that fish and other creatures need to lay their **eggs** on the bottom.

Plants need **nutrients** to live and grow. The two most important nutrients are **nitrogen** and **phosphorous**. People add nutrients to the land in various ways.

a. **Fertilizer** contains large amounts of nutrients. Farmers add fertilizer to their fields to help the growth of crops and pasture.
b. Homeowners also use fertilizer to help their gardens and lawns grow.

c. Livestock, such as cattle, chickens and pigs raised for food, produce **animal waste** that contains large quantities of nitrogen and phosphorous. Pet waste can be a problem if it is not collected and disposed of properly.
d. Human **sewage** also contains nutrients. Sewage is treated in wastewater treatment plants or in septic systems

High levels of nutrients in water cause illness in both humans and animals High levels of nutrients in water can also cause **algae blooms**. Microscopic algae in the water begins to reproduce rapidly when there are high levels of nutrients in the water. When the short life cycle of algae ends and they die, they sink to the bottom of the water, where they **decompose** as bacteria begin to consume them. Then the bacteria multiply, and they use more and more **oxygen**. As the **oxygen** in the water is used up, fish and other creatures that use oxygen may die.

How is land use related to nonpoint source water pollution?

The way people use the land can cause water pollution. Wise use of the land does not cause pollution but unwise use of the land often does. Before the land was settled by European immigrants, most of it was covered by **trees**. Trees protect streams from pollution in various ways.

a. The leaves and roots of trees prevent erosion.
b. Leaves shade streams, keeping the temperature cool.
c. Roots take in nutrients before they can enter the water in runoff.

When the land was settled, many trees were cut down, and the land became more susceptible to erosion. Livestock left nutrient-rich waste on the ground. People also began to use fertilizers, and such chemicals as weed killers (herbicides) and pesticides on farms, golf courses and lawns

As the land was developed further, the amount of **impermeable** surface covering the land increased. Impermeable surfaces, such as rooftops, roads, and parking lots, do not allow water to seep into the ground. When stormwater cannot sink into the ground, it runs off the ground downhill into the nearest body of water. Stormwater runoff causes several problems.

a. more erosion of the land
b. stream banks and bottoms are damaged by erosion
c. more nonpoint source pollution is washed into the water
d. less water has a chance to sink into the ground and recharge the **groundwater**
e. **flooding** can occur downstream

How can nonpoint source water pollution be prevented?

Sediment is most easily kept out of waterways by preventing erosion. Plant cover prevents erosion. When plants are removed during construction, for example, grass seed can be spread and straw mulch used to protect the seed until it begins to grow. Shrubs and trees provide even more protection than grass.

The amount of nutrients carried into the water by runoff can be minimized in various ways. Farmers and homeowners should apply fertilizer sparingly on the basis of a soil test to insure that there is no excess fertilizer that plants cannot use and which can become a source of water pollution. Livestock can be fenced out of streams to keep their waste out of the water. Pet waste should be collected and disposed of with the trash. Homeowners with septic systems should have them inspected on a regular basis and pumped out when needed.

Limiting the amount of impermeable surface on the surface of the land is another way to prevent nonpoint source pollution. The amount of runoff increases as the amount of impermeable surface increases, and it is runoff which carries nonpoint source pollution into the water in the first place. Keeping more areas planted, and limiting the width of roads and the size of parking lots can help reduce runoff. Catching roof runoff in rain barrels or storage tanks helps reduce the amount of runoff. Rain gardens can be planted to catch runoff and give it a chance to sink into the ground.

The best way to protect streams and other bodies of water from nonpoint source pollution is to establish buffers. A **stream buffer** is an area along a stream in which natural vegetation is allowed to grow to a width of 35 feet or more.

Color Me a Watershed

Through interpretation of maps, students observe how development can affect a watershed. This activity is a good follow-up to watershed mapping. Three options are given to help the teacher match the lesson plan with the level and ability of each class.

Level(s): 6-8

Subject(s): Life Science; Geography; Social Studies; Mathematics; History

Virginia SOLs: 6.7 a,c,d,f; 6.9 a,c,d; LS12 a,b,e; PS1 c,f,k,l; Math 6.1, 6.9d

Objectives:
Students will be able to:
1. Explain how population growth and settlement cause changes in land use, and consequently, in land cover.

2. Explain how land use in a watershed can affect the runoff of stormwater.

Materials:
1. Copies of *Maps A*, *B* and *C*
2. (Optional) Maps and/or photographs of the community showing changes over time.
3. colored pencils (for Option 1)
4. calculators (for Options 2 and 3)
5. copies of the chart *Area of Land Coverage* (for Options 2 and 3)
6. copies of the chart *Volume of Rain and Volume of Runoff* (for Options 2 and 3)

Estimated Time: 45-50 minutes

Background Information: *Watersheds and Changes in Land Use*, p.16.

Preparation:
1. Collect photographs of the community in which your school is located from 50 to 100 years ago.

2. Ask students to talk with parents and/or grandparents about what changes they have observed in the community, with emphasis on development and changes in land use.

Activity Procedure:
1. Discuss what changes have occurred in the local community during the last 100 years. Ask students to share what changes they, and their parents and grandparents have observed in the community. If you have photographs of the community documenting changes over the last 100 years, share them with the class for discussion.

2. Discuss how changes in the community have affected the amount of water that infiltrates into the ground during stormwater evens. Has the amount of impervious surface increased significantly? Is there a stormwater system that pipes runoff into local streams? Is there any evidence of erosion of stream banks? Has the water quality in local streams or rivers changed? Are local wells being drilled to a deeper depth than they were 20 or 25 years ago?

3. Tell the students that maps can be used to study changes in land use and answer questions such as the ones above. Hand out copies of **Maps A**, **B** and **C**. Explain that they represent aerial views of a watershed taken at different times. To simplify map interpretation, the borders of the watershed coincide with the edges of the grid. In addition, the outlines of various types of land areas (e.g., wetlands, forests) align with grid lines. The following are three options for interpreting changes in the watershed presented on the maps. **Option 1** may be more appropriate for younger students, but can help all students complete **Options 2** and **3**. Students must be able to multiply and calculate percentages to complete the second and third options.

Option 1

1. have the students look at *Maps A, B* and *C*. Explain that they represent changes in this land over a 100-year period. Have students look at the key for each map. Instruct them to designate each land area with a different color (e.g., color all forest areas green). They should use the same color scheme for all the maps.

2. When students finish coloring, have them compare the sizes of the different areas on each map and among the maps. Ask them to compare the plant cover and land use practices in each period. They may note changes in cropland, forest, grassland, wetland, urban land use, etc.

3. Discuss one or more of the following questions:
   - What happens to the amount of forested land as you go from *Map A* to *Map C*?
   - Which map has them most land devoted to human settlement?
   - Where are most of the human settlements located?
   - What effect might these human settlements have on the watershed?
   - Would you have handled development differently?

Option 2

1. Have students determine the land area of each of the maps. Each unit on the grid represents one square kilometer. There are 360 square kilometers (or 360,000,000 square meters) on each map.

2. For each map, have students determine how much area is occupied by each type of land coverage (e.g., forest, wetland, and farmland). Responses can be guesses or exact calculations. For example , for *Map A*, 17 of the grid units are occupied by wetlands. By dividing 17 by the total number of units (360), students can calculate that 4.7% of the land area is wetlands. The amount of land allotted to wetlands, forests, etc. will change for each map, but the amount of stream coverage (111 squares or 30.8%) will remain constant. Students should record their answers in the *Area of Land Coverage* chart.

NOTE: Most watershed calculations employ standard measurements: inches and cubic feet per second (cfs). However, to facilitate students' calculations, metric measurements are used here.

3. Tell students that the watershed has received 5 cm (0.05 m) of rain. (Although rain does not normally fall evenly on a large area, assume that the 5 cm of rain fell evenly over the entire watershed.) By converting both the rainfall and the land area to meters, students can calculate the amount of water (m^3) which fell on the land. 18,000,000 m^3 of rain fell on the watershed (0.05m x 360,000,000 m^2 = 18,000,000 m^3). This might seem like a large quantity of water, but if 5 cm of rain did fall evenly on a watershed of this size, the watershed would receive this volume of water.

NOTE: 100 cm = 1 m; 1,000,000 m^2 = 1 km^2

4. Ask the students to estimate the amount of water that would be drained from the land into the river. Tell students that for the watershed represented by *Map A*, 2,767,500 m^2 of rain was runoff (i.e., the water flowed into the river and did not soak into the ground, did not evaporate and was not used by plants or animals). (Runoff values are provided by the *Answer Key* below. In **Option 3**, students will calculate runoff for each land area.)

5. Discuss changes in land coverage represented in *Maps A* through *C*. Ask students if they think the amount of runoff would increase or decrease.

6. Tell students that when 12,450,000 of rain fell on the land represented by *Map A*, 1,922,500 was runoff. For Map B 2,871,500 was runoff. Discuss the following questions in addition to those listed in **Option 1**:
   - Which absorbs more water, concrete or forest (or wetlands, or grasslands)?
   - Which map represents the watershed that is able to capture and store the most water?
   - What problems could arise if water runs quickly over surface material, rather than moving slowly or soaking in?
   - How might the water quality of the river be affected by changes in the watershed?

Option 3

1. Have students determine how the figures in **Option 2** were obtained. In the chart *Volume of Rain and Volume of Runoff*, each land area has been assigned a proportion of the water that is not absorbed or that runs off its surface. Using the information from this chart and from the Area of Land Coverage chart, have students calculate the amount of water that each land area does not absorb. For example, for the forested land in Map A, 189 km^2 x 1,000,000 m^2/km^2 = 189,000,000 m^2 of land. Multiply this by the amount of rainfall (189,000,000 m^2 x 0.05 m = 9,450,000 m^3). Since 10% of the rainfall was runoff, 945,000 m^3 of water drained into the river from the forested land (9,450,000 m^3 x .20).

Note: The figures for percent runoff are based on hypothetical data. To determine how much water is absorbed by surface material, one needs to know the soil type, texture, slope, vegetation, intensity of rainfall, etc. In addition, many farms and urban areas practice water conservation measures that help retain water and prevent it from flowing over the surface of the land. The information in the chart is intended only for practice and comparisons.

Wrap Up and Action

1. Have students summarize how changes in land us e affect the quantity and quality of runoff in a watershed. Discuss land use practices in the community and how they may affect water discharge in the watershed. Take students on a walking tour around the school and note areas that contribute to or reduce stormwater runoff. (for example, roof, parking lots, paved roads and sidewalks promote runoff; parks, wetlands, and trees capture water.)

Assessment Opportunities:

1. Have students compare the land area occupied by farms, towns and natural areas in a watershed during different time periods. (**Options 1** and **2**)

2. Have students describe how surface runoff is influenced by changes in land use. (**Options 2** and **3**)

3. Have students calculate quantities of runoff from different land areas in a watershed (**Option 3**)

Extensions:

1. Take students on a walking or bus tour of the community and observe land use in the watershed and how it may contribute to absorption or runoff of stormwater. If digital cameras are available, record various types of land use and create a bulletin board of factors in the community that contribute to or reduce runoff.

2. Have students draw maps of how they think the community will look in 100 years. Alternatively, have them draw two maps, of the best-case scenario and the worst-case scenario regarding development that will decrease or increase runoff.

3. Have students research ways that development can proceed without increasing runoff. Discuss Low Impact Development techniques that can reduce runoff (see suggested links below).

Additional Reference Material:

Low Impact Development

- www.nrdc.org/water/pollution/storm/chap12.asp
- www.lid-stormwater.net/intro/background.htm

Adapted from **Project WET Curriculum and Activity Guide**, pp. 223-231. © www.projectwet.com

Area of Land Coverage (Chart for Option 2)

	Map A 100 yrs ago		Map B 50 yrs ago		Map C Present	
Land Coverage	**km²**	**%**	**km²**	**%**	**km²**	**%**
Forest						
Grassland						
Wetland						
Residential						
Agriculture						
Stream						

Answer Key: Area of Land Coverage

	Map A 100 yrs ago		Map B 50 yrs ago		Map C Present	
Land Coverage	**km²**	**%**	**km²**	**%**	**km²**	**%**
Forest	189	52.5	162	45	114	31.7
Grassland	20	5.6	14	3.9	6	1.7
Wetland	17	4.7	13	3.6	5	1.4
Residential	13	3.6	33	9.2	58	16.1
Agriculture	10	2.8	27	7.5	66	18.3
Stream	111	30.8	111	30.8	111	30.8

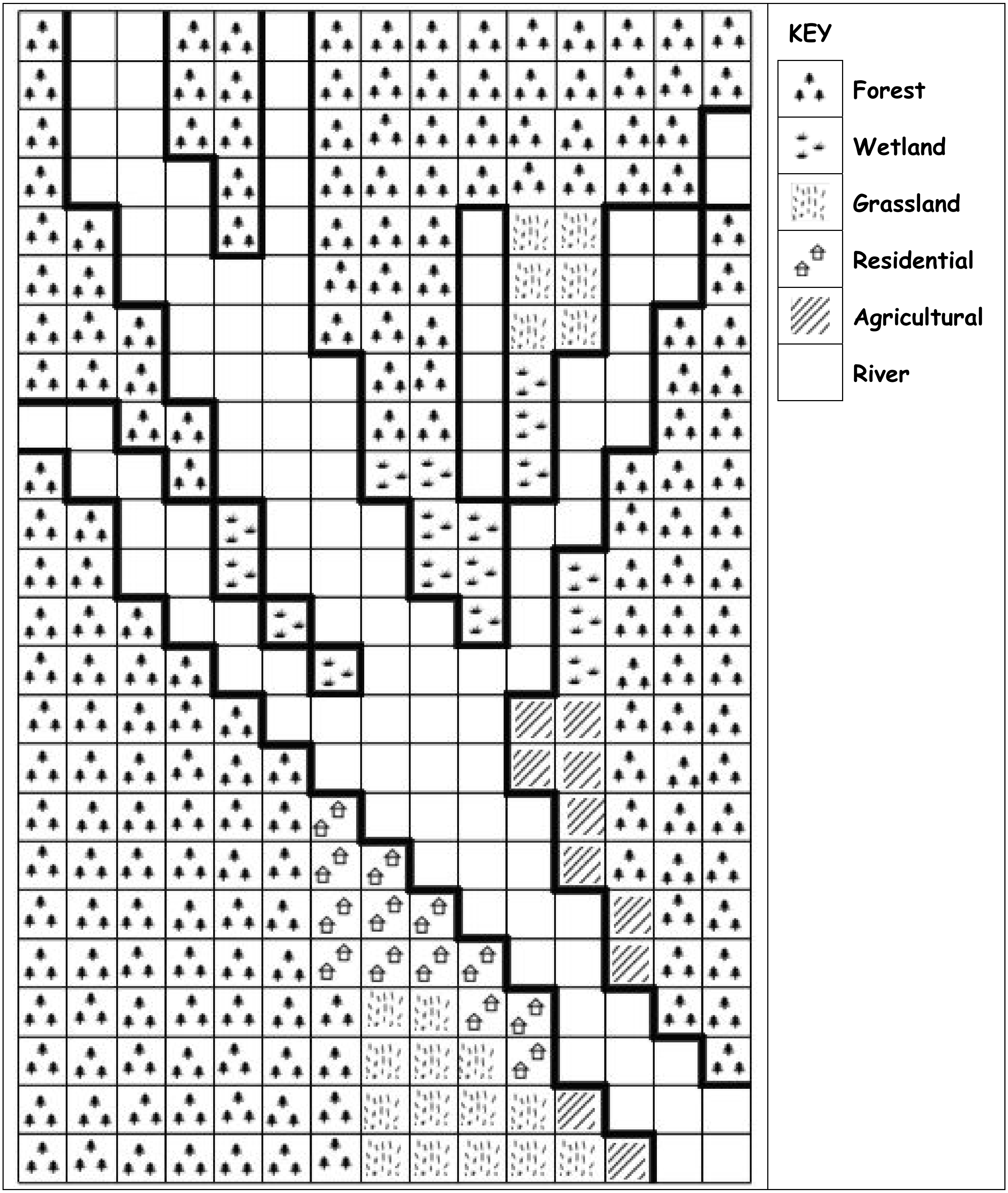
Volume of Rain and Volume of Runoff (Chart for Option 3)

	Map A 100 years ago		Map B 50 years ago		Map C Present	
Land Cover and % Runoff						
Forest 10% Runoff						
Grassland 20% Runoff						
Wetland 5% Runoff						
Residential 90% Runoff						
Agriculture 30% Runoff						
Total Runoff						
Total Runoff + Stream Discharge (5,550,000 m^3)						

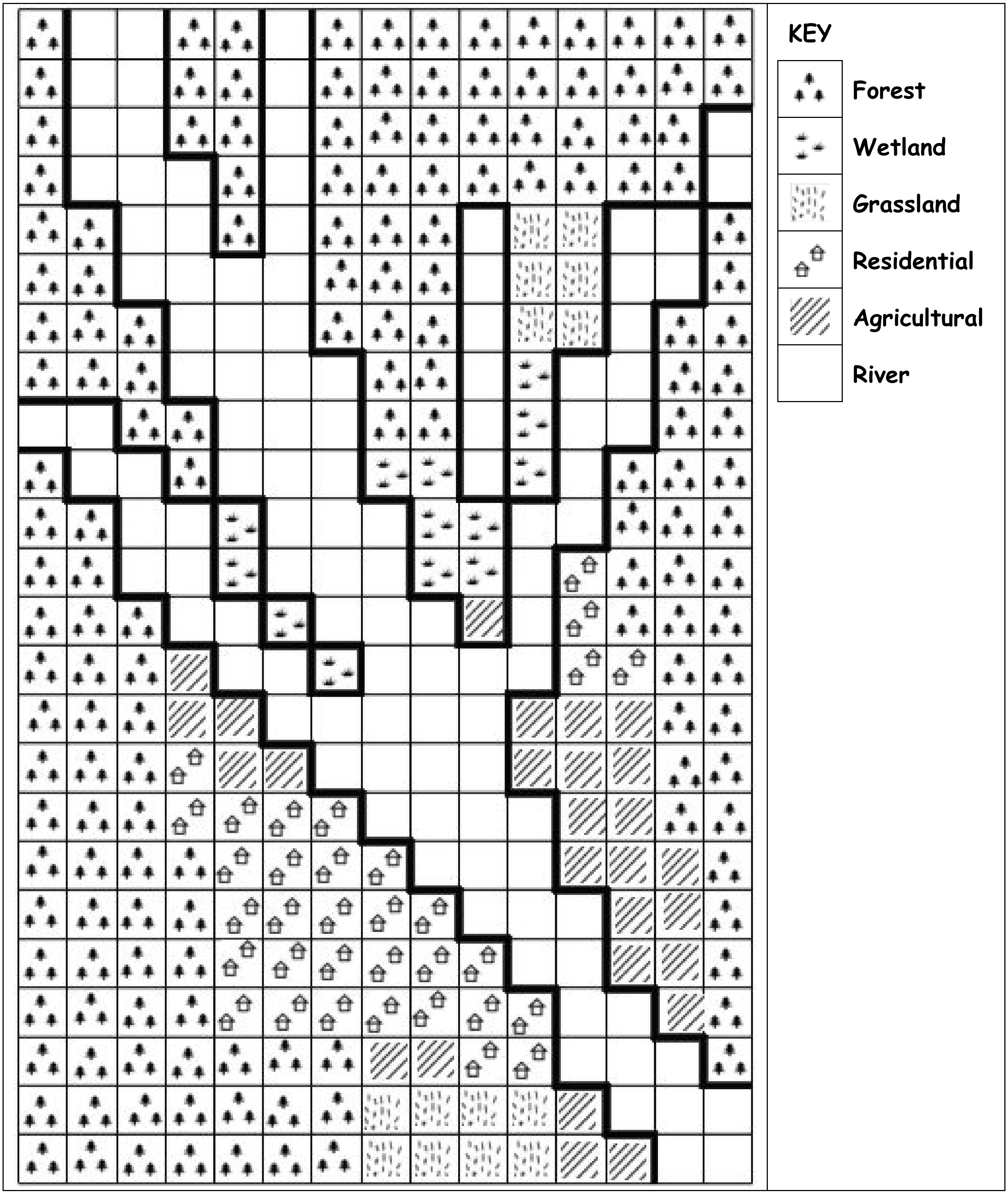
Answer Key: Volume of Rain and Volume of Runoff

	Map A 100 years ago		Map B 50 years ago		Map C Present	
Land Cover and % Runoff	**Volume m^3**	**Runoff m^3**	**Volume m^3**	**Runoff m^3**	**Volume m^3**	**Runoff m^3**
Forest 10% Runoff	9,450,000	945,000	8,100,000	810,000	5,700,000	570,000
Grassland 20% Runoff	1,000,000	200,000	700,000	140,000	300,000	60,000
Wetland 5% Runoff	850,000	42,500	650,000	32,500	250,000	12,500
Residential 90% Runoff	650,000	585,000	1,650,000	1,485,000	2,900,000	2,610,000
Agriculture 30% Runoff	500,000	150,000	1,350,000	405,000	3,300,000	990,000
Total Runoff		1,922,500		2,871,500		4,242,500
Total Runoff + Stream Discharge (5,550,000 m^3)		7,472,500		8,421,500		9,792,500

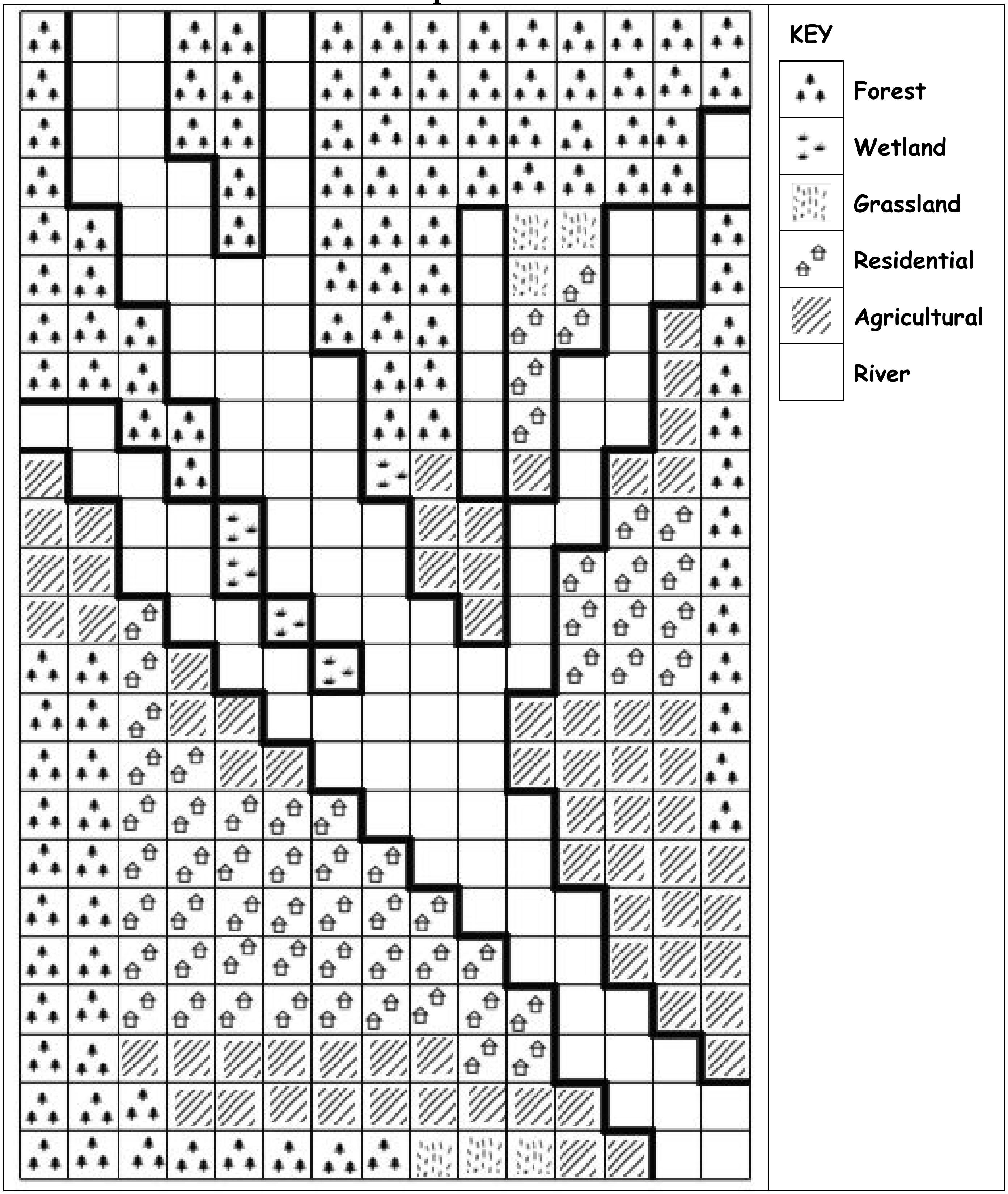
Map A: 100 Years Ago



Map B: 50 Years Ago



Map C: Present



Watersheds and Changes in Land Use

Resource Managers and policymakers use maps to monitor land use changes that contribute to increased amounts of stormwater runoff flowing into rivers and streams. Vast amounts of public and private time, energy and money have been invested in research projects specifically designed to collect land use data. Land uses that are monitored include urban (residential, parks and businesses); agriculture (pastures and cropland); industry; transportation systems (roads, railroads and trails); and public lands (refuges, parks and monuments).

Land use changes can have significant impact on a region's water resources. Streams, lakes and other bodies of water collect water drained from the surrounding land area, called a watershed or drainage basin. After periods of precipitation or during snowmelt, surface water is captured by soil and vegetation, stored in ground water and in plants and slowly released into a collection site (e.g., a stream).

Resource managers are developing and using Geographic Information Systems (GIS) to store data and generate land use maps electronically. Although the process of collecting the data is tedious work, the ease of generating usable maps and map overlays is significant. For example, a water manager can generate a map that shows a river's watershed and major tributaries, its floodplains, and the location of urban dwellings (homes and businesses), to display areas likely to be impacted by floods. This information is valuable to local governments, planners, realtors, bankers, homeowners, and others. This map could also be compared to similar land use maps from 10, 20 or 30 years ago.

One way watershed managers study drainage basins is by measuring streamflow. Determining how much water is discharged by a watershed involves measuring the amount of water (volume) that flows past a certain point over a period of time (velocity). Streamflow is measured in cubic feet per second (cfs) or cubic meters per second (cms).

By measuring the amount of water flowing through a stream channel over a period of years, scientists calculate average streamflow. When streamflow changes significantly from its normal quantities, watershed managers investigate reasons for this change. The amount of water discharged by a watershed is influenced by soil conditions, vegetative coverings, and human settlement patterns. Wetlands, forests, and prairies captures and store far more water than land covered by buildings, paved roads and parking lots. Consequently, urban areas have more runoff than areas covered with vegetation.

Water managers carefully assess land use changes and set development policy accordingly. For example, in areas that are susceptible to erosion, the incorporation of soil conservation measures (e.g., planting cover crops on farmland and establishing grassed waterways) can significantly reduce erosion and the amount of sediment carried into streams. Managers may designate lands so susceptible to erosion that landowners are required to plant vegetation on them (or preserve existing vegetation). In urban areas, local governments may set aside natural areas to serve as filters for stormwater runoff, based on runoff data and stream water quality problems. In each situation, using maps to understand past and preset and use helps water managers better predict future problems.

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