Color Me a Watershed

■ **Grade Level:** High School

■ **Subject Areas:** Environmental Science, Mathematics, History

■ **Duration:**
Preparation time:
Option 1: 10 minutes
Option 2: 10 minutes
Option 3: 10 minutes
Activity time:
Option 1: 40 minutes
Option 2: 50 minutes
Option 3: 40 minutes

■ **Setting:** Classroom

■ **Skills:** Gathering information (calculating); Analyzing (comparing); Interpreting (identifying cause and effect)

■ **Charting the Course**
Prior to this activity, students should have a general understanding of watersheds ("Rainy-Day Hike" and "Branching Out!"). Activities in which students compare runoff from different surfaces are "Capture, Store, and Release" and "Just Passing Through."

■ **Vocabulary**
discharge, watershed, runoff

What might make a watershed blue . . . or brown . . . or green?

Summary

Through interpretation of maps, students observe how development can affect a watershed.

Objectives

Students will:

- recognize that population growth and settlement cause changes in land use.
- analyze how land use variations in a watershed can affect the runoff of water.

Materials

- *Maps and photographs of community, past and present* (optional)
- *Copies of* ***Maps A, B,*** *and* ***C***

For Option 1:

- *Colored pencils*

For Options 2 and 3:

- *Calculator*
- *Copies of the chart* ***Area of Land Coverage***
- *Copies of the chart* ***Volume of Rain and Volume of Runoff***

Making Connections

Learning about the past refines our current perspectives and helps us plan for the future. Historical, sequential maps provide graphic interpretations of watershed history. By comparing past and current land use practices, students can recognize trends in development; this knowledge can help them appreciate the importance of watershed management.

Background

Resource managers and policymakers use maps to monitor land use changes that could contribute to increased amounts of runoff flowing into a river. 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, but are not limited to: urban (residential, parks, and businesses); agriculture (pastures and corn, soybean, wheat, sunflower, tomato, pineapple, and lettuce production); industry; transportation systems (roads, railroads, and trails); and public lands (refuges, parks, and monuments).

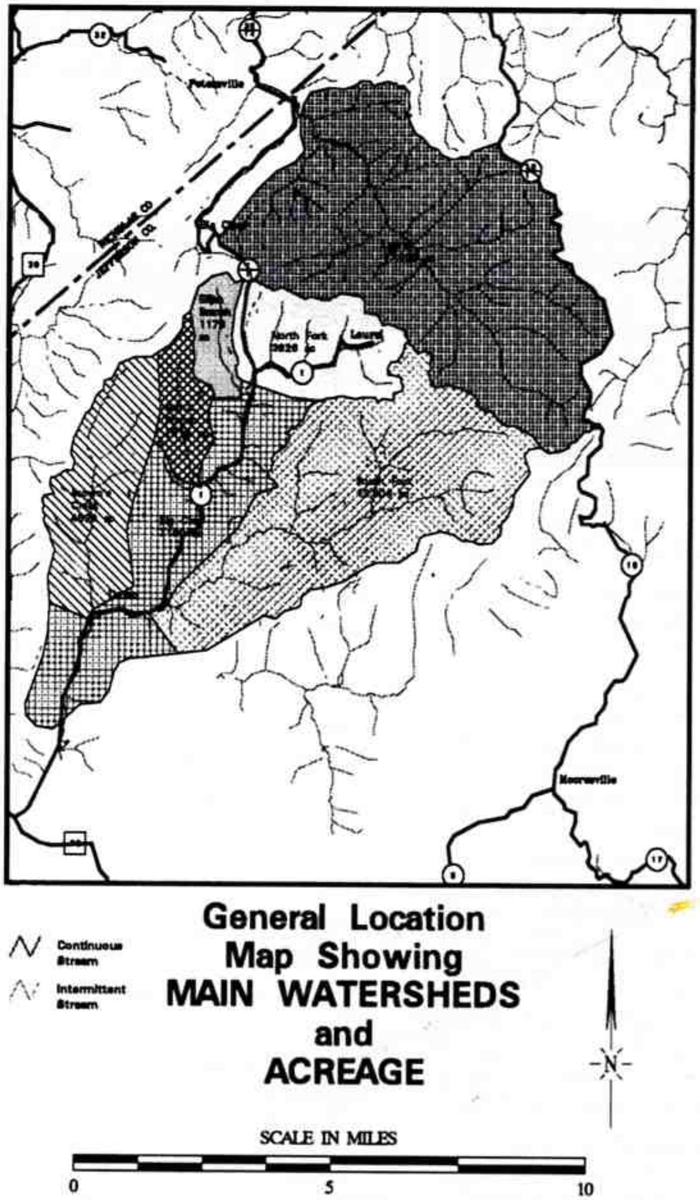
Land use changes can have significant impact on a region's water resources. Streams, lakes, and other bodies of water collect water drained from the surrounding land area, called a watershed or drainage basin. After periods of precipitation or during snowmelt, surface water is captured by the soil and vegetation, stored in ground water and in plants, and slowly released into the 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 could generate a map that shows a river's watershed and major tributaries, its floodplains, and the locations 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 anomaly. The amount of water discharged by a watershed is influenced by soil conditions, vegetative coverings, and human settlement patterns. Wetlands, forests, and prairies capture and store more water than paved roads and parking lots. Consequently, urban areas will 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 stream sediment load. Managers may designate lands so susceptible to erosion that landowners are required to plant vegetation on them. In urban areas, local governments may set aside natural areas to serve as filters for storm water runoff, based on runoff data and stream water quality problems. In each situation, using maps to understand past and present land use helps water managers better predict future problems.



Sample GIS map.

Procedure

▼ *Warm Up*

What did the land and water around cities like Los Angeles, Portland, Minneapolis, Houston, Chicago, New Orleans, Miami, or Washington, D.C., look like 100 or 50 years ago? How has growth changed each region? Ask students to imagine their community 100 years ago. They may want to refer to old photographs or news stories. Was the school in existence? What happened when water fell on the ground then, compared to now? If a body of water is near the school, would its appearance and condition have been altered over the years? Tell students that maps can teach us about the past and possibly answer questions such as these.

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▼ *The Activity*

Provide students with 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 land areas (e.g., wetlands, forests) align with grid lines.

Following are three options for interpreting changes in the watershed presented on the maps. The first option may be more appropriate for younger students, but can help all students complete **Options 2** and **3**. Students should be able to multiply and calculate percentages to complete the second and third options.

Option 1

1. **Tell students to 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 maps.

2. **When students finish coloring, have them compare the sizes of the different areas on each map and among maps.** Ask them to compare plant cover and land use practices in each of these periods. They may note changes in croplands, forests, grasslands, wetlands, urban land uses, 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 the most land devoted to human settlements?
- 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 in the grid represents 1 square kilometer; there are 360 square kilometers (or 360,000,000 m^2) 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 should 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' computations, 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 over 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 (0.05 m x 360,000,000 m^2 = 18,000,000 m^3). Of this 18,000,000 m^3 of rain, 5,550,000 m^3 landed on the stream (111,000,000 m^2 x 0.05 m = 5,550,000 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 stream would receive this volume of water. (**NOTE:** 100 cm = 1 m; 1,000,000 m^2 = 1 km^2.)

4. **Ask students to estimate the amount of water that would be drained from the land into the stream.** Tell students that for the watershed represented by *Map A*, 2,767,500 m^3 of rain was runoff (i.e., the water flowed into the stream and did not soak into the ground, did not evapo-

ANSWER KEY: AREA OF LAND COVERAG3E

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage	km^2	%	km^2	%	km^2	%
Forest	189	52.5	162	45	111	30.8
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	69	19.2
Stream	111	30.8	111	30.8	111	30.8

rate, and was not used by plants or animals). (Runoff volumes are provided in the *Answer Key* below. In **Option 3**, students can 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 m^3 of rain fell on the land represented by *Map A*, 2,767,500 m^3 was runoff. For *Map B*, 3,612,500 m^3 was runoff. For the *Map C*, 4,797,500 m^3 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 stream be affected by changes in the watershed?

Option 3

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 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 20% of the rainfall was runoff, 1,890,000 m^3 of water drained into the stream 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 soil type and texture, slope, vegetation, intensity of rainfall, etc. In addition, many farms and urban areas practice water conservation measures that help retain water

ANSWER KEY: VOLUME OF RAIN AND VOLUME OF RUNOFF

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff	(9.45×10^6) 9,450,000	(1.89×10^6) 1,890,000	(8.1×10^6) 8,100,000	(1.62×10^6) 1,620,000	(5.55×10^6) 5,550,000	(1.11×10^6) 1,110,000
Grassland 10% runoff	(1.0×10^6) 1,000,000	($.1 \times 10^6$) 100,000	($.7 \times 10^6$) 700,000	($.07 \times 10^6$) 70,000	($.3 \times 10^6$) 300,000	($.03 \times 10^6$) 30,000
Wetland 5% runoff	($.85 \times 10^6$) 850,000	($.0425 \times 10^6$) 42,500	($.65 \times 10^6$) 650,000	($.0325 \times 10^6$) 32,500	($.25 \times 10^6$) 250,000	($.0125 \times 10^6$) 12,500
Residential 90% runoff	($.65 \times 10^6$) 650,000	($.585 \times 10^6$) 585,000	(1.65×10^6) 1,650,000	(1.485×10^6) 1,485,000	(2.9×10^6) 2,900,000	(2.61×10^6) 2,610,000
Agriculture 30% runoff	($.5 \times 10^6$) 500,000	($.15 \times 10^6$) 150,000	(1.35×10^6) 1,350,000	($.405 \times 10^6$) 405,000	(3.45×10^6) 3,450,000	(1.035×10^6) 1,035,000
Total runoff		2,767,500		3,612,500		4,797,500
Total runoff plus stream discharge (5,550,000 m^3)		(8.3175×10^6) 8,317,500		(9.1625×10^6) 9,162,500		(10.347×10^6) 10,347,500

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and prevent it from streaming over the surface. The information in the chart is intended only for practice and comparisons.

▼ *Wrap Up and Action*

Have students summarize how changes in the land 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 community, and note areas that contribute to or reduce storm runoff. (For example, parking lots, paved roads, and sidewalks promote runoff; parks, wetlands, and trees capture water.)

Students could attend a public meeting in which changes in land use for their community are being discussed.

If students were to draw a fourth map of the same area 100 years in the future, how would it appear? Have students plan a city that contributes positively to a watershed. They should contact city planners or conduct library research to support their projections.

Assessment

Have students:

- compare land area occupied by farms, towns, and natural areas in a watershed during different time periods (**Options 1** and **2**).
- describe how surface runoff is influenced by changes in land use (**Option 2**).
- calculate quantities of runoff from different land areas in a watershed (**Option 3**).

Upon completing the activity, for further assessment have students:

- design a city plan that regulates urban runoff.

Extensions

Have students explore changes in their own community. Sources of historical and current maps include the Natural Resource Conservation Service, the Bureau of Land Management, the U.S.D.A. Forest Service, the U.S. Geological Survey, or a local public works department. Sometimes libraries contain historical, hand-drawn maps from the 1700s to the 1900s. Resource people in these agencies or the community will also have information and perspectives about past, present, and future water use.

Students may want to conduct a more accurate analysis of the degree to which different surface areas are permeable to water. Contact conservation agencies or extension agents in the community to learn how different soil types affect runoff.

Several books for young people powerfully describe and illustrate the effects of human development on land areas. Students may want to compare the changes indicated by the maps to changes portrayed in *Window*, by Jeannie Baker, or other sources.

Students can use computer technology to increase their understanding of geographical features, through Geographic Information Systems (GIS). Contact Charlie Fitzpatrick, ESRI K-12 Education and Libraries, 3460 Washington Drive, Suite 101, St. Paul, MN 55122. (612) 454-0600, ext. 26).

Or e-mail cfitzpatrick@esri.com for information about how to order and use ArcView, a computer program that enables learners to investigate GIS files.

Resources

🍎 Baker, Jeannie. 1991. *Window.* New York, N.Y.: Greenwillow Books.

Guling, Cynthia L., and Kenneth I. Helphand. 1994. *Yard Street Park.* New York, N.Y.: John Wiley & Sons.

Huff, Barbara A. 1990. *Greening the City Streets: The Story of Community Gardens.* St. Louis, Mo.: Clarion Publishing Co.

Leopold, Luna B. 1974. *Water: A Primer.* San Francisco, Calif.: W. H. Freeman & Co.

Patterson, Mark, and Ron Mahoney. 1993. *Environmental Education Software and Multimedia Source Book.* Moscow, Idaho: University of Idaho Agricultural Publications.

Smith, Daniel S., and Paul Cawood Hellmund. 1993. *Ecology of Greenways.* Minneapolis, Minn.: University of Minnesota Press.

Notes ▼

Name: ______________________________ Date: ______________

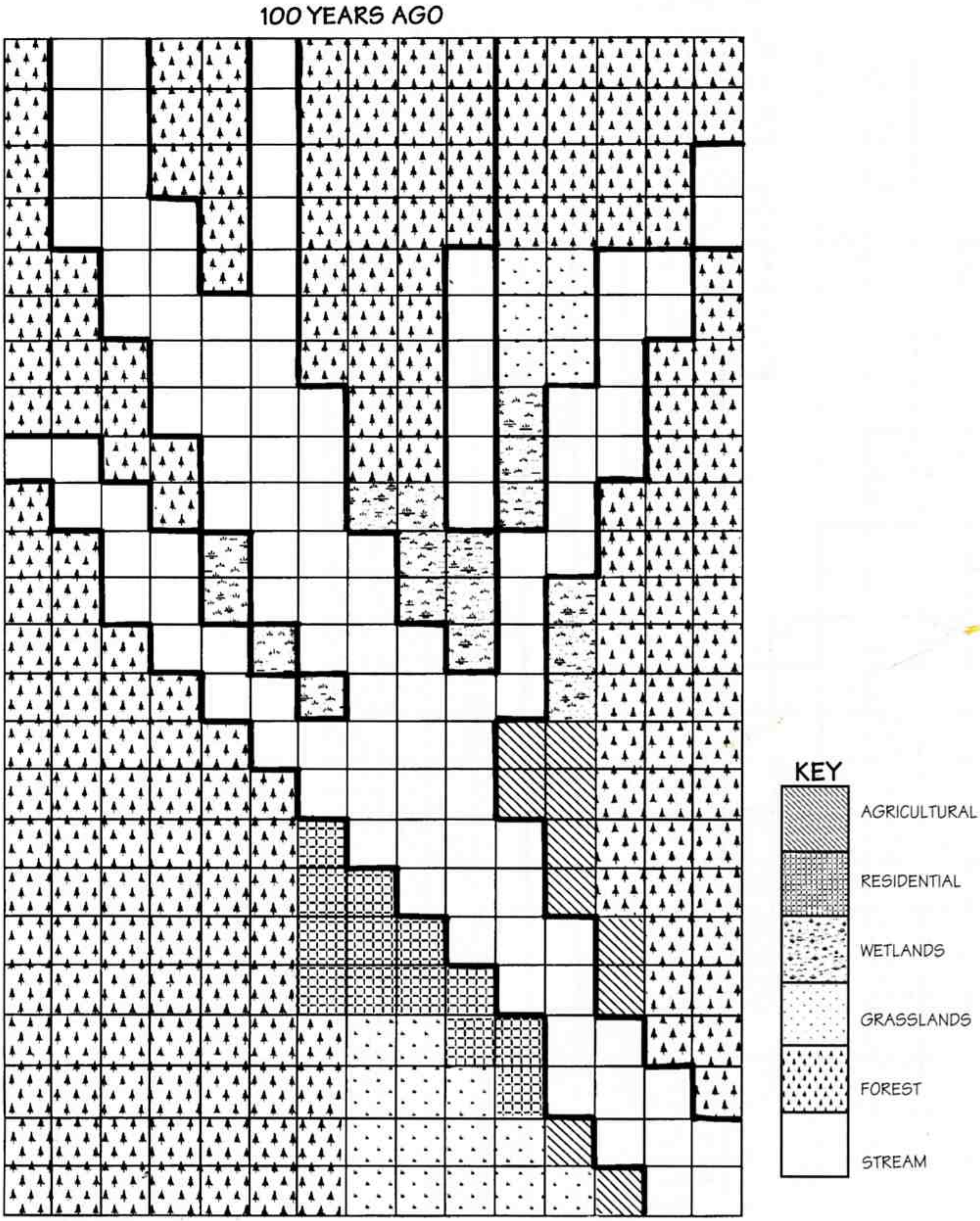
Chart for Option 2 AREA OF LAND COVERAGE

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage	km^2	%	km^2	%	km^2	%
Forest						
Grassland						
Wetland						
Residential						
Agriculture						
Stream						

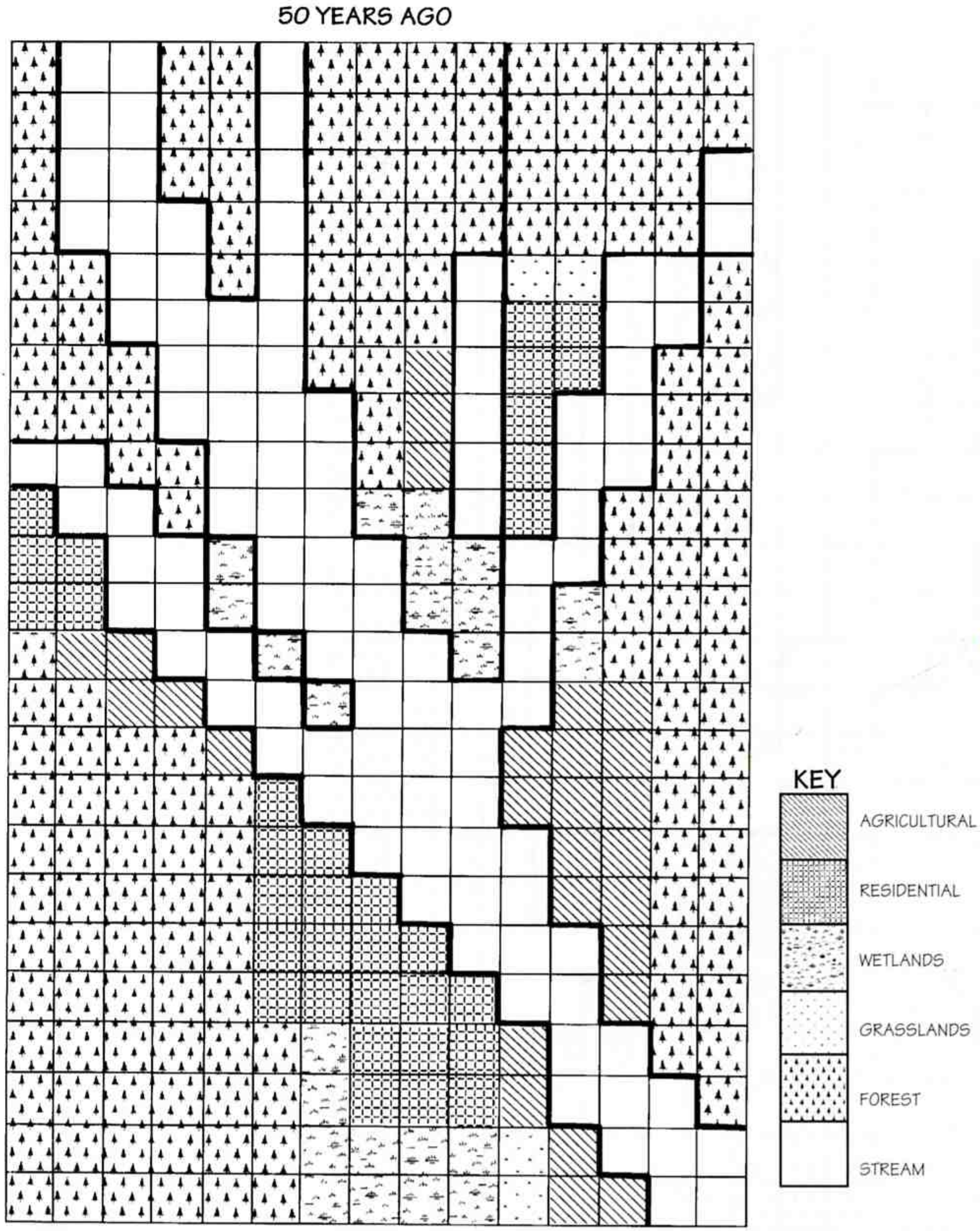
Chart for Option 3 VOLUME OF RAIN AND VOLUME OF RUNOFF

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff						
Grassland 10% runoff						
Wetland 5% runoff						
Residential 90% runoff						
Agriculture 30% runoff						
Total runoff						
Total runoff plus stream discharge (5,550,000 m^3)						

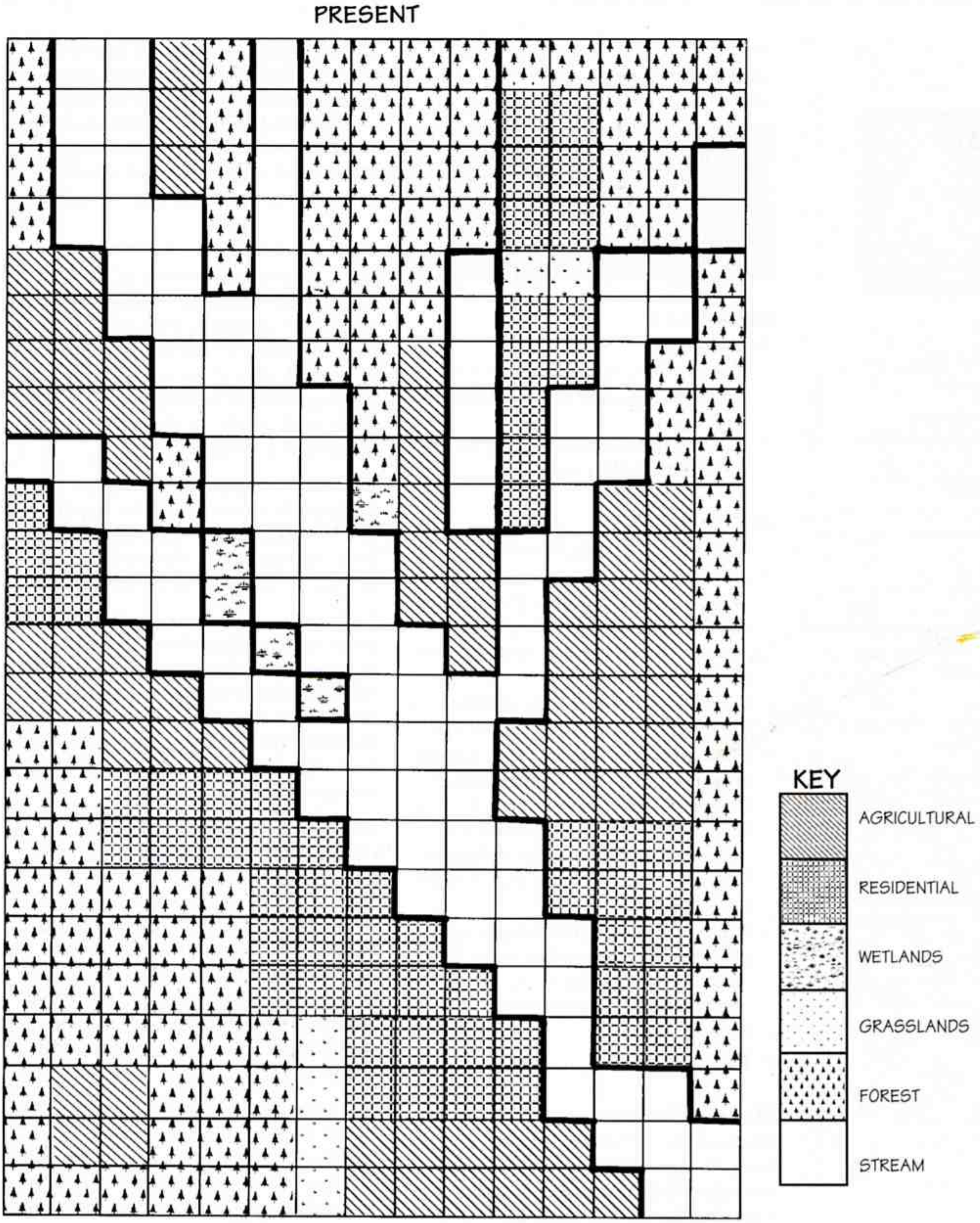
Map A


100 YEARS AGO
KEY
AGRICULTURAL
RESIDENTIAL
WETLANDS
GRASSLANDS
FOREST
STREAM

Map B


50 YEARS AGO
KEY
AGRICULTURAL
RESIDENTIAL
WETLANDS
GRASSLANDS
FOREST
STREAM

Map C


PRESENT
KEY
AGRICULTURAL
RESIDENTIAL
WETLANDS
GRASSLANDS
FOREST
STREAM