Activity 2 How Does Your Community Maintain Its Water Supply?

Goals

In this activity you will:

- Create and manipulate physical models of surface-water and ground-water supply systems.
- Explain how a change in one part of the water-supply system creates changes in other parts of the system.
- Understand the main ways that a community can increase its water supply.
- Compare and contrast surface-water systems and ground-water systems.
- Analyze the water-supply system in your community.

Think about It

You and others in your community expect to always have the water you need when you turn on the faucet.

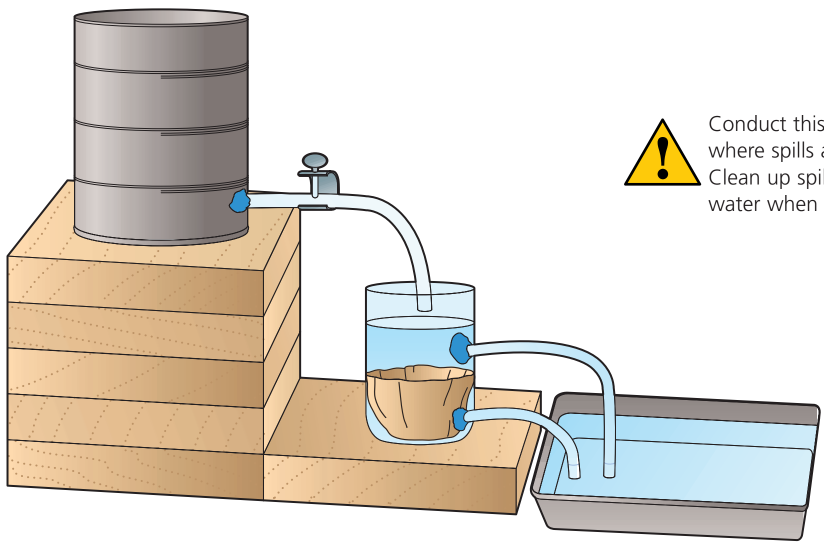
- How can any community guarantee that there will be enough fresh water available to meet the needs for personal, recreational, business, industrial, and agricultural use?
- Suppose your region were experiencing a severe and prolonged drought. Would ground water or surface water be a more reliable water supply? Explain your response.

What do you think? Record your ideas in your *EarthComm* notebook. Be prepared to discuss your responses with your small group and the class.

Investigate

Part A: Modeling a Surface-Water Supply System

1. Set up a coffee can, a clear, 750 mL soda bottle (top cut off), and a shallow container as shown in the diagram.
2. Line the inside of the bottle with coffee filter paper. (This keeps sand from entering the plastic tubing.)
3. Pour sand into the filter until the bottle is one-third full of sand.
4. One kind of surface-water reservoir is one in which a river is dammed to make a lake that a community can use for its water supply. Assume that the ideal situation is a balance between a flow of water into the reservoir and the flow out of the reservoir. Water flows out of the reservoir not only for community use but also to return to the river downstream of the community. Water flow for both of these uses can be controlled by a system of valves.



Conduct this investigation where spills are not a problem. Clean up spills. Dispose of the water when done.

Identify the following parts of the water supply system on the model that you set up:

- precipitation, river flow, reservoir inflow;
- surface-water reservoir;
- ground-water reservoir;
- ground-water withdrawal/outflow (for the community);
- surface-water withdrawal/outflow (for the community);
- total community consumption.

  a) Draw a box model (systems diagram) of the physical model, with reservoirs and flows. Label the reservoirs and flows.

5. Release the clamp slightly to allow water to flow into the bottle. Observe what happens with the flow of water out of the bottle. Adjust the flow until you have a steady-state system (in which reservoir inflow equals reservoir outflow).
   a) Record what you see.
   b) How did the two water-supply reservoirs respond to the increase in precipitation?
6. Release the clamp completely to allow a full flow of water from the can. Observe what this does to the flow of water out of the bottle.
   a) Record what you see.
   b) How did the water-supply reservoirs respond to a decrease in precipitation?
7. Tighten the clamp so that the flow comes to a trickle. Again, allow the system to reach a steady state. Observe what this does to the flow of water out of the bottle.
   a) Record what you see.
   b) Which reservoir lasted longer during the "drought"?
8. Finally, tighten the clamp to stop the flow of water.
   a) Observe and record the results.
9. In your model, you did not control community consumption (water flowed out of the reservoirs despite a decrease in recharge into the reservoirs).
   a) Where would you place additional clamps on the model to keep water in both reservoirs during a drought?
   b) What would these clamps represent in the real world?
10. What would you add to the model to show the return of water from the community to the system shown in your model and to other parts of the system not shown (for example, communities downstream)?
   a) Make a diagram to show your ideas.
11. How could you use a graduated cylinder and a stopwatch so that your model allows you to measure the rate of flow of water from one system reservoir to another (flux)?
   a) Record your ideas in your *EarthComm* notebook.
   b) Add flux arrows to the box model you drew.

Part B: Modeling Ground-Water Supply

1. Your teacher will cut a hole about 1 cm across in a dish tub, on the bottom and very close to where the surface curves upward to one of the end walls of the tub.
2. Cover the hole from the inside with two or three pieces of duct tape.

   With a sharp pencil, punch a circular hole in the duct tape, from the inside of the tub, to be about 3 mm in diameter.
3. Pour sand evenly into the dish tub, making a small depression (a low spot) near the center of the sand surface. Make the depression about 5 cm deep and about 10 cm across, with gently sloping sides. The depression represents a shallow lake

Wear safety goggles. Clean up spills immediately. Dispose of water when you are done.

or wetland. The diagram illustrates the arrangement in the tub.

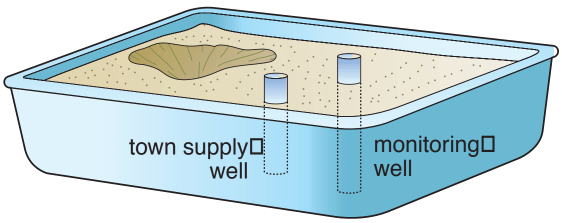
4. Place the tub where water can drain harmlessly from the hole in the bottom.

5. Cover one end of a piece of the rigid tubing with a layer of cheesecloth and tape it to the sides of the tubing with duct tape.

   Bury the tubing to stand vertically in the sand, about 10 cm away from the center of the depression. The lower end of the tubing should be about 5 cm from the bottom of the tub. This represents a town water supply well.

6. Cover one end of another piece of rigid tubing with a layer of cheesecloth and tape the cheesecloth to the sides of the tubing.

   Bury the tubing to stand vertically in the sand, about 10 cm away from the center of the depression. The lower end of the tubing should be only about 0.5 cm from the bottom of the tub. This represents a monitoring well.



7. Each member of your group needs to assume one of the following roles: a water supplier, a consumer, a well monitor, and a data recorder.

8. Establish an equilibrium ground-water system with a water table high enough for there to be water in the lake. Follow these steps:

   - The water supplier starts supplying water at a rate of 1000 mL/min. The water supplier pours a steady supply of water onto the sand at the "upstream" end of the tub (the end opposite the hole in the bottom of the tub). The best way to do this is to measure out a constant volume of water in a measuring cup and pour that water into the tub every 15 or 30 seconds.
   - The data recorder can then record the rate of supply. This represents ground-water recharge from infiltration of precipitation into the ground surface.
   - The well monitor will monitor the test well by dipping a chopstick ruler gently into the well until it rests on the bottom and then reading the position of the water surface in the well.

9. Continue supplying water and monitoring the well until the level of the water table stops changing.

   If there is no surface water in the depression, increase the rate of water supply and monitor the test well until the height of the ground-water table stops changing.

   Repeat the process until there is water in the depression.

10. Now it's time to start extracting water from the supply well.

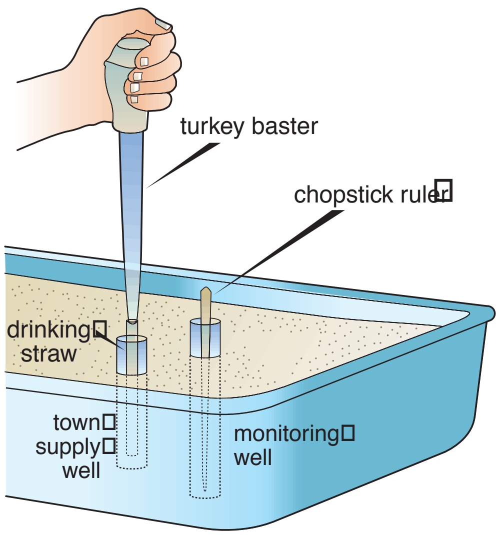
    To do this, tape a drinking straw to the end of the turkey baster and seal the joint with a wrap of duct tape.

11. The consumer should then squeeze the bulb of the baster, insert the straw into the bottom of the well, and **slowly** release the bulb.

12. Keep track of the volume of water extracted per minute. Try to keep the rate of extraction constant, minute after minute.

    The data recorder should record the rate of withdrawal.

13. Meanwhile, the well monitor should monitor the test well and record the height of the water table every minute.



14. Depending on the rate of extraction relative to the rate of recharge, three outcomes of this part of the investigation are possible:

    Mark the baster and chopstick ruler as laboratory equipment. Dispose of the drinking straw.

- A new equilibrium height of the water table in the test monitoring well is established, and some water remains in the depression.
- A new equilibrium height of the water table in the test monitoring well is established, but the depression has lost its water.
- The supply well runs dry; that is, the rate of withdrawal cannot be maintained.

Try to reproduce each of these outcomes, by adjusting the rate of withdrawal from relatively low to relatively high.

15. Use the results of this part of the investigation to answer the following questions:

    a) What is the difference between a renewable ground-water supply and a nonrenewable ground-water supply? What do you think it means to "mine" ground water?

    b) Under what conditions in this part of the investigation were you using a renewable supply of ground water? Under what conditions might you have been using a nonrenewable supply of ground water?

    c) Do you think it would have been less likely to lower the water table if you had obtained a given rate of supply by pumping water from two nearby supply wells instead of only one? Explain your answer.

Part C: Water Supply in Your Community

1. You will be able to find the answers to some of these questions in your water supplier's consumer confidence report, also called a water quality report. For some of the other questions, appoint one student in your group or class to call your community's water supplier to ask. The *EarthComm* web site also provides links.

   a) What kind of municipal water system does your community use? What factors do you think affected their selection of the system?

   b) How does your community evaluate potential development projects in light of water supply?

   c) What contingency plans does your community have in order to deal with potential droughts?

   d) Every freshwater system requires maintenance and upkeep. What does this mean for your community, and what does it cost?

   e) Determine the average cost per gallon of water for your community and three others in or near your county. List the factors that account for the differences in the cost per gallon. Does the cost vary? Why?

   f) Determine the gallons-per-person use for your own community and two neighboring communities. List the factors that could account for the differences.

Reflecting on the Activity and the Challenge

You learned that many factors affect the operation of a community's water supply system. Some of these factors are drought, increased demand, and the needs of other communities. You also learned that a system consists of many parts and that a change in one part of the system affects other parts of the system. You also took a closer look at the impact of consumption on ground-water supplies. You then analyzed the water-supply system in your community. Understanding these factors will help you evaluate whether your community's water-supply system is capable of handling the extra demands of the three new developments proposed in the **Chapter Challenge**.

Digging Deeper

WATER SUPPLIES

Sources of Water Supplies

In colonial times in the United States, most people took water from rivers or dug their own wells. Today, cities and towns need reliable and safe supplies of water for their citizens. Water must be collected, stored, and treated. There must be enough water to see a community through times of drought and times of increased water use. The two main water sources are surface waters, from rivers and lakes, and ground water.

Figure 1 Surface water from freshwater lakes is a valuable source for human use.

Figure 2 Large pumps are used to supply water to a community.

There are six ways to increase the supply of water to a community:

- withdrawing water from ground-water aquifers;
- withdrawing water directly from nearby rivers or lakes;
- building dams to create reservoirs to store runoff;
- improving the efficiency of water use through water conservation;
- transporting water from a distant area by means of aqueducts;
- converting salt water to fresh water.

Many of these choices affect other communities. For example, if one town takes water from a river, it decreases the amount of water available to towns downstream.

Surface Water

In most rivers, water flow is too variable from season to season to be a reliable direct source of water supply. Most surface-water supplies are from large lakes of artificial reservoirs, which fluctuate less from season to season or from year to year.

Dams, such as the one shown in *Figure 3*, are beneficial in providing a water source and controlling floods, but they have disadvantages as well. Reservoirs behind dams displace wildlife and people, and they cover cropland. Dams can disrupt the natural migration of fish. The sediment carried by a river is deposited in the reservoir behind the dam. Over time, the reservoir slowly fills up with sediment, leaving less room for water.

Ground Water

Ground water for water supply is pumped from porous material below the surface. Three concepts are important in understanding ground-water supplies. **Porosity** is a measure of the percentage of pores (open spaces) in a material. **Permeability** is a measure of how easy it is to force water to flow through a porous material. An **aquifer** is any body of sediment or rock that has sufficient size and sufficiently high porosity and permeability to provide an adequate supply of water from wells. The best aquifers consist of loose and porous sand and gravel, although fractured bedrock can also form good aquifers.

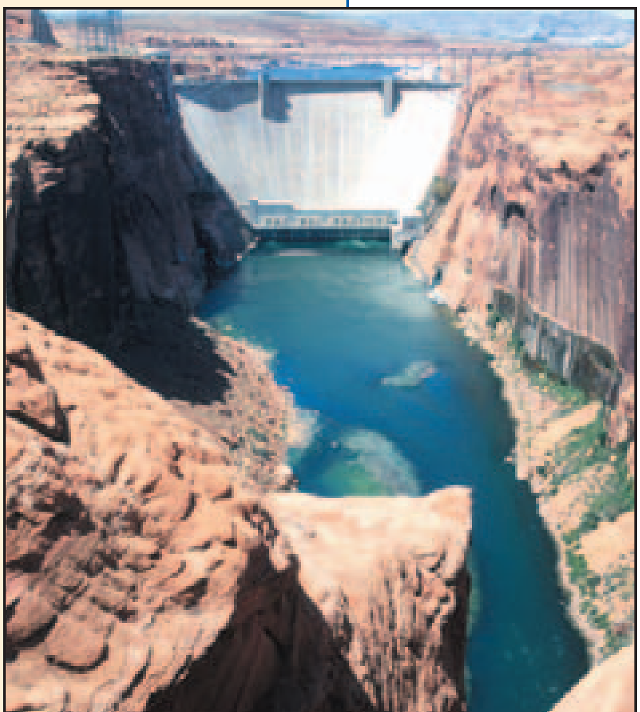


Figure 3 A large reservoir was created from the Colorado River at the Glen Canyon Dam, Arizona.

Geo Words

porosity: a measure of the percentage of pores (open spaces) in a material.

permeability: a measure of how easy it is to force water to flow through a porous material.

aquifer: any body of sediment or rock that has sufficient size and sufficiently high porosity and permeability to provide an adequate supply of water from wells.

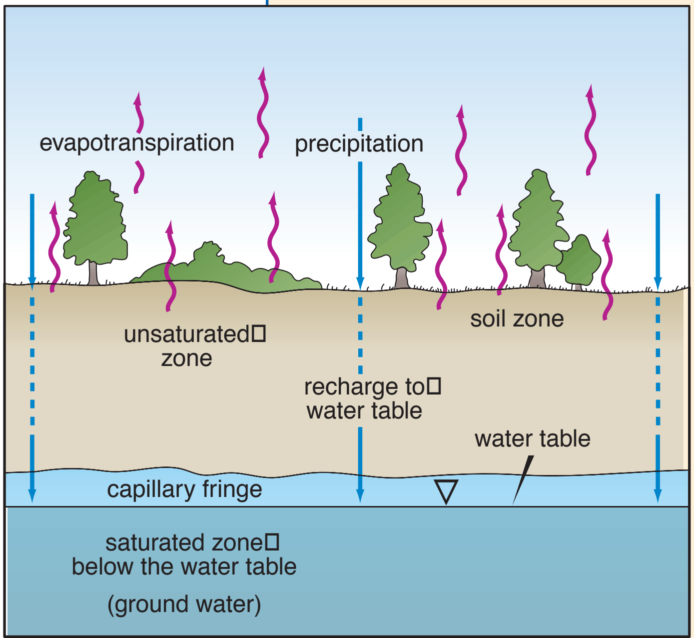


Figure 4 The main two zones of the ground-water system—saturated and unsaturated. The water table marks the upper surface of the saturated zone.

Down to a certain depth below the surface, the pores in the sediment and rock are mostly filled with air, except when water is percolating downward after a heavy rain. This is called the unsaturated zone. Eventually the downward-moving water reaches a zone called the **saturated zone**, where all of the pores are filled with water. The top of the saturated zone is called the **water table**. These zones are illustrated in *Figure 4*. The water table can be located at the surface in places next to rivers and lakes, and also in wetlands. In some areas it can lie many tens of meters below the surface.

Because ground water must move through small pores it flows very slowly. Ground water speeds of a meter per day are considered high. Speeds as low as a meter per year are common. In general, the smaller the pore spaces between the grains, the slower the ground water flows. Ground water moves from areas where the water table is relatively high to areas where it is relative low. *Figure 5* shows the flow of ground water in a typical landscape.

Geo Words

saturated zone: the zone, beneath the water table where all of the pores are filled with water.

water table: the surface between the saturated zone and the unsaturated zone (zone of aeration).

evapotranspiration: loss of water from a land area through transpiration of plants and evaporation from the soil and surface water.

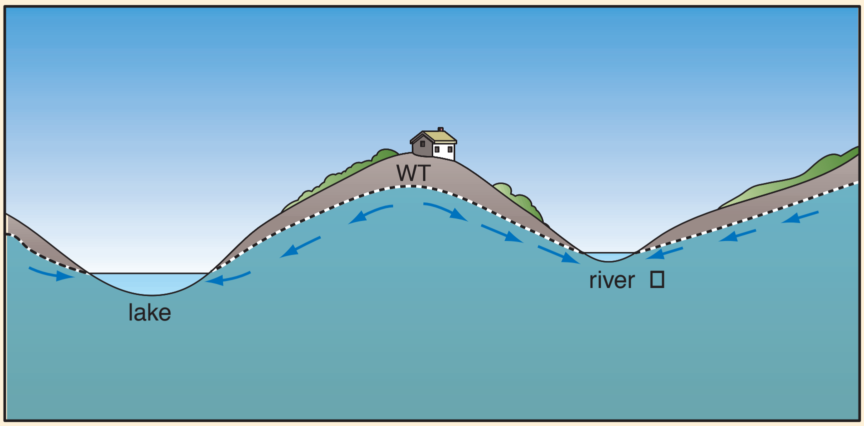


Figure 5 The water table (WT) is shown as a dashed line. The blue arrows show the direction of ground-water flow.

In rural areas, most homes have their own wells to tap ground water. Many towns, and even some small cities, obtain part or all of their water supply from several large wells that pump ground water from large aquifers.

Most aquifers, called **unconfined aquifers**, have a free connection upward to the surface. The water in these aquifers is replenished by downward percolation of surface water from directly above. The sand in your model was an unconfined aquifer. Addition of new water to an aquifer by downward flow of surface water is called **recharge**.

Figure 6 The signs show the approximate position of the land surface in 1925, 1955, and 1977 in the San Joaquin Valley, California. Switching to surface water slowed the rate of land subsidence, but new ground-water pumping during a drought from 1987 to 1992 caused further subsidence.

Some aquifers are isolated from the surface by an overlying layer of very impermeable material, called an **aquiclude**. Layers of fine clay are especially effective aquicludes. Confined aquifers cannot be recharged from directly above. The recharge area for a confined aquifer may be located far away, tens or even hundreds of kilometers.

In many areas where ground water has been used for a long time, the land surface has subsided (sunk down) because so much water has been withdrawn. For example, at Edwards Air Force Base in California, the land has subsided more than two meters, damaging some of the runways once used by the Space Shuttle.

Geo Words

unconfined aquifer: an aquifer that has a free connection upward to the surface.

recharge: addition of new water to an aquifer by downward flow of surface water.

aquiclude: a body of rock that will absorb water slowly, but will not transmit it fast enough to supply a well.

Aqueducts

In areas where water use is greater than local supplies, as in southern California, water must be brought in from distant areas where water is abundant. About two-thirds of California's precipitation falls in the north, but about two-thirds of the population lives in the south. A system of reservoirs in northern California supplies southern California with water that is transported through a system of large surface pipes and channels, called **aqueducts**, like the one shown in *Figure 7*. Over long distances the water in the aqueducts flows downhill under gravity, but in some places enormous pumping plants must raise the water up over hills and mountains.

Figure 7 This aqueduct in southern California carries much needed water over long distances.

Desalination

Converting sea water to fresh water, a process called **desalination**, is still too expensive to be widely used. It is used in some arid countries that are located near the ocean. Israel and Saudi Arabia obtain much of their water from desalination. As new and less expensive techniques for desalination become developed, the process will be a more and more important source of fresh water in many countries.

Water Conservation

Conservation is a great way for a community to stretch its water supplies further without having to develop new supplies. Although the water supply stays the same, if the community uses less, then there will be more water for new development. You will learn more about conservation in later activities.

Geo Words

aqueduct: a system of large surface pipes and channels used to transport water.

desalination: the process of removing dissolved salts from sea water in order to make it potable.

Check Your Understanding

1. Describe six possible ways to increase the supply of water to a community.
2. What are the advantages of building a dam to provide a source of surface water? What are the disadvantages?
3. Explain how porosity and permeability of Earth materials are important when considering ground water as a water source.
4. Why is desalination of ocean water not a practical source of water supply?

Understanding and Applying What You Have Learned

1. Look at the diagram of the surface-water reservoir.

    a) Write down the major parts of the water-supply system. Also, think about the parts that may not be shown.

    b) Which part of the system do people have the least control over? Why?

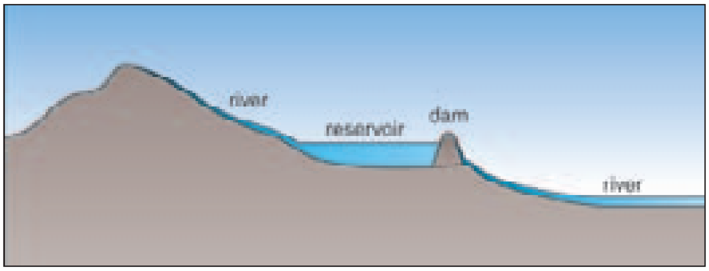
    c) Which part of the system do people have the greatest control over? Why?

    d) How might the volume of water entering the reservoir from the river vary from season to season?

    e) How might the amount of fresh water that a community needs vary from season to season?

    f) Assume there is a severe drought. How might the system respond in order to guarantee the amount of fresh water needed by the community?

    g) What other factors can be manipulated in times of drought to make the system operate as efficiently as possible?



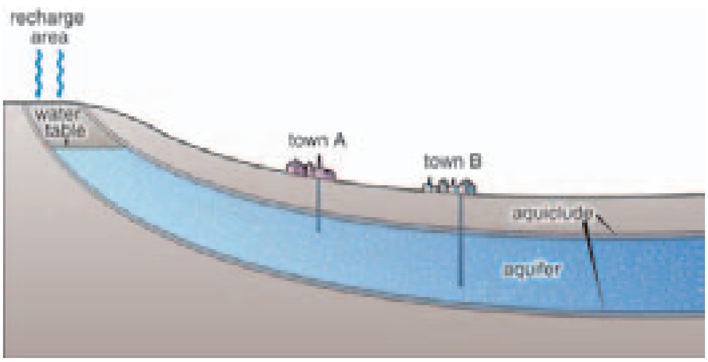
A surface-water reservoir.

2. Look at the diagram of the confined aquifer.

    a) What factors would affect the level of fresh water in this aquifer?

    b) What will happen if the volume of water entering at the recharge area decreases and the demand for fresh water from the wells remains the same? When would this situation be likely to occur? Which wells would be affected first?

    c) Assume that the ground water enters the aquifer at a constant rate. What would the community need to know before agreeing to a development project that would result in a significant increase in water use?



A confined aquifer.

3. a) Suppose that the capacity of the ground-water supply is sufficient to meet the increased needs of a new development in your community. The development is approved. How will this affect other communities using the same ground water in the future?

   b) Should this have any effect on your community's decision to approve the development? Explain why or why not.

4. Compare and contrast the advantages and disadvantages of using ground water versus surface water.

5. Suppose your community's water supplier proposed building a dam on a nearby river to increase water supply. Make a list of the pros and cons of damming a river in your community.

Preparing for the Chapter Challenge

Using what you have learned in this activity and your community's water quality report, determine how much water the proposed developments will use per year. As a class, decide on the number of houses that will be included in the area.

Does your community have an adequate water supply to meet this demand now and over the next 25 years?

Inquiring Further

1. **First American reservoirs**

   Visit the *EarthComm* web site to do some research on the first reservoirs constructed in America. When and where were they built? How did they work?

2. **First American ground-water systems**

   Visit the *EarthComm* web site to conduct some research on the first ground-water systems developed in America. When and where were they built? How did they work?

3. **Water supplies in desert cities**

   Pick a large desert city, such as Las Vegas or Phoenix. Conduct some research to find out how these cities maintain a water supply.

4. **Water needs of a golf course**

   How much water does it take to run a golf course? You have already established an estimate for your community's water use. Pick several communities in parts of the United States with a very different climate from yours. Find out how much water an average golf course uses in those communities. What accounts for the differences in water use?