Buried Treasure: Oklahoma's Aquifers

Objective
Students will read about the hydrologic cycle, groundwater and aquifers, locate aquifers in Oklahoma and build models to show the permeability of different earth materials.

Background
WHAT IS AN AQUIFER?

The Earth and its atmosphere is a closed hydrologic cycle which contains a set amount of water. This water is recycled naturally. Rain that falls today may evaporate to fall as snow in the Colorado Rockies, where it might stay for months or years before melting, evaporating and falling as rain, which is absorbed into the soil and finally enters an aquifer or groundwater system. There is 100 times more water in the ground than in all the world's rivers and lakes.

An aquifer is like a very large, saturated underground sponge made of sands and gravels. Water seeps through this sponge at different rates, depending on the permeability of the sands or gravel. When water enters the saturated zone, it becomes part of the ground water. The top of this saturated zone is called the water table. The water table may be very close to the ground surface, especially if it is near a body of water, or it may be 200 to 600-feet deep.

A water-bearing soil or rock formation that can provide enough water for human use is called an aquifer. The word "aquifer" literally means "water bearer." The rock below the Earth's surface is called bedrock. If all bedrock consisted of a dense material like solid granite, gravity would have a hard time pulling water downward. But Earth's bedrock consists of many types of rock, such as sandstone, granite, and limestone. Bedrock can become broken and cracked, creating spaces that can fill with water. Some bedrock, such as limestone, is dissolved by water. This creates large spaces that fill with water. In bedrock aquifers, the water can move through the cracks in the rock. Some types of bedrock—like sandstone—can absorb water like a sponge.

How quickly water passes through the soil depends on the size and shape of the soil particles, the amount of pore space between the particles, and whether or not the pore spaces interconnect. For example, soils that consist primarily of larger sand and gravel particles tend to have larger, interconnected pore spaces that allow water to flow easily and quickly. Other soils, like silts and clays, have poorly connected pore spaces that slow down the flow of water.

Aquifers are filled slowly. For this reason, aquifers can dry up when they are drained faster than they can be refilled. This process is called "aquifer depletion." Aquifers can be drained by man-made wells or they can flow out naturally in springs.

THE OGALLALA AQUIFER

Aquifers are very important to farmers in areas where there is little rainfall. In the Oklahoma Panhandle, where rainfall averages less than 20 inches a year, farmers depend on groundwater from the Ogallala Aquifer for irrigating the

Oklahoma Academic Standards

GRADE 3
Life Science: 4-3,4. Earth Science: 3-1
Economics Literacy: 2.3.
Geography: 3.1BC, 2.C.
History: 4.9

GRADE 4
Earth Science: 1-1; 2-1,2; 3-1
Geography: 1.1AB, 3, 4 5
Algebra: 2.2. Geometry: 2.5; 3.2

GRADE 5
Life Science: 1-1; 2-2. Earth Science: 2-1,2, 3-1
Math Content—5.G.A.2

GRADE 6
Earth Science: 2-4; 3-3
Geography: 1.1,2,5; Regions: 2.1B; Physical Systems: 3.1AB, 2; Human Systems: 4.5; Environment: 5.2B, 5AC
Algebra: 2.3. Measurement: 3.3,4

grain they grow to feed their cattle. Also called the High Plains Aquifer, this groundwater system underlies about 174,000 square miles in one of the major agricultural regions in the world, including the Oklahoma Panhandle, Colorado, Kansas, Nebraska, New Mexico, South Dakota, Texas, and Wyoming. Thirty percent of the water used for irrigation in the US comes from this aquifer and about 95 percent of all the water from the Ogallala is used for irrigation. The aquifer is named after the town of Ogallala, Nebraska.

The Ogallala aquifer lies near the land surface in most places. The average depth of the aquifer is 100 feet, with a maximum depth of about 1,000 feet in Nebraska and between 0 and 400 feet in the Texas Panhandle. In the Oklahoma Panhandle the aquifer depth ranges from fewer than 50 feet to between 400 and 600 feet. Water in aquifers moves downhill. In the Southern High Plains the water moves northwest to southeast at about 150 feet per year under natural conditions. This rate of movement can be altered by discharge from the aquifer by pumping wells.

FORMATION OF THE OGALLALA

The Ogallala Aquifer was formed beginning 10 to 12 million years ago during late Tertiary (Miocene/Pliocene) geologic time. Sand, gravel, silt, and clay was carried by eastward-flowing streams from upland areas to the west and north and deposited over the land surface of the present-day High Plains. Sediments from the erosion were deposited on low hills, in shallow valleys, and in meandering streams. As a result, the Ogallala Formation is deeper where these sediments filled stream channels and more shallow where hills or upland areas were buried.

AGRICULTURAL USE OF THE OGALLALA AQUIFER

Early settlers on the High Plains may have thought the water flowing underground would last forever. By the 1930s, farmers and ranchers had begun to realize the potential of the aquifer for irrigation. In the High Plains region, the total number of acres irrigated with ground water expanded rapidly after 1940, from 2.1 million acres in 1949 to 13.9 million acres in 1997.

In the early days of irrigation, very little water conservation equipment or technology was available. As a result, large amounts of water were lost to evaporation and deep percolation. Open, unlined ditches were used to move the water from the well to the field being irrigated. Water losses could range from 10 to 30 percent per 1,000 feet of ditch. High pressure, hand-moved sprinklers had evaporation losses of up to 50 percent.

In the 40 years between 1940 and 1980, water levels in the Ogallala declined more than 100 feet in some places. During that period irrigation water was discharged from the aquifer at a rate 10-40 times greater than the recharge rate from precipitation. The low average rainfall in the area is partly responsible for the low recharge rate, but even when it does rain, it can take as many as 35 years for recharge water to reach the aquifer. There is currently enough water in the Ogallala Aquifer to cover the entire state of Oklahoma two feet deep, but water levels are declining.

Materials

two dry sponges

zip closing plastic bags

clear plastic cups, 2 3/4” deep X 3 1/4” wide

modeling clay or floral clay

white play sand

small pebbles or natural-colored aquarium gravel (Rinse before using.)

bucket of clean water and small cup to dip water from bucket

soap pump

nylon stocking for covering the bottom of the soap pump

rubber bands

funnels

coffee filters

large aluminum pans

WATER CONSERVATION

Through the years, irrigation technology has allowed agricultural producers to use water more efficiently without waste. Across the High Plains region, farmers have adopted more-efficient watering techniques like center pivot or drip irrigation and conservation practices such as drought-resistant crops.

Numbers compiled by the US Geologic Survey show overall water use from the Ogallala peaked in the 1970s with a steady decline since. Between 1995 and 2005 total yearly use of water for irrigation declined from more than 600 million gallons per year to less than 220 million gallons per year.

OTHER AQUIFERS IN OKLAHOMA

The Ogallala aquifer is classified as a bedrock aquifer, an aquifer composed of consolidated material such as limestone, dolomite, sandstone, siltstone, shale or fractured crystalline rock. Oklahoma has other ancient bedrock aquifers that provide groundwater for irrigation. These include the Antlers, Central Oklahoma, Elk City, Rush Springs and Vamoosa-Ada aquifers.

Oklahoma also has alluvial and terrace aquifers. These are aquifers formed by material laid down in a river channel or on a floodplain. Alluvial aquifers are connected to nearby streams and rivers and interchange water rapidly with rivers and streams. Alluvial and terrace aquifers in Oklahoma include the Cimarron River, Enid Isolated terrace, North Canadian River (northwest and central), and the Tillman terrace aquifers.

Social Studies

1. Read and discuss background and vocabulary
2. Provide copies of a US map. A map is included with this lesson.
   —Students will locate the eight states listed in the background that are affected by the Ogalalla Aquifer.
   —Students will use online search engines or library resources to find the area in each state where the aquifer is located and color in those areas on the map.
   —Students will use online and library resources to determine the average rainfall in areas where the Ogallala Aquifer is located. Students will write papers explaining how the Ogalalla Aquifer can make up for low rainfall.
3. Students will use online or library resources to locate the aquifer nearest your school.
   —Students will research to find more information about the aquifer—how it was formed, the geologic era in which it was formed, the classification (bedrock or alluvial), etc.
   —Students will report the results of the research in writing and share the results with the class.
4. Students will use online or library resources to find other aquifers in Oklahoma.

Vocabulary

absorb— to take in or suck or swallow up

aquifer— a water-bearing unit of rock, sand, or gravel capable of holding and releasing water of good quality

alluvial— soil material (as clay, silt, sand, or gravel) deposited by running water

center pivot— a method of crop irrigation in which equipment rotates around a pivot and crops are watered with sprinklers.

conservation— a careful preservation and protection of something, especially planned management of a natural resource to prevent exploitation, pollution, destruction, or neglect

crop rotation— the practice of growing a series of different types of crops in the same area in sequential seasons

deposit— to let fall or sink, as silt deposited by a flood

discharge— to give forth fluid or other contents

drip irrigation— an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters

elevation— the height to which something is raised

erode— to wear away by or as if by the action of water, wind, or glacial ice

evaporate— to pass off into vapor from a liquid state

geologic— a science that deals with the history of the earth and its life especially as recorded in rocks

groundwater— water underneath the earth's surface that supplies well and springs

Vocabulary

hydrologic— a science dealing with the characteristics, distribution, and circulation of water on and below the surface of the land and in the atmosphere
irrigate— to supply with water by artificial means
meander— to follow a winding or complicated course
pore— a tiny opening or space
percolation— the act of trickling or causing to trickle through something porous
permeable— having pores or openings that permit liquids or gases to pass through
pivot— a shaft or pin on which something turns
precipitation— water or the amount of water that falls to the earth as hail, mist, rain, sleet, or snow
recharge— a hydrologic process where water moves downward from surface water to groundwater
recycle— repeat a process from the beginning
saturated— soaked or filled with something to the point where no more can be absorbed or dissolved
sediment— material (as stones and sand) deposited by water, wind, or glaciers
Tertiary— of, relating to, or being the earliest period of the Cenozoic era of geological history marked by the formation of high mountains (as the Alps and Himalayas) and the rise in importance of mammals on land
water table— the surface of the water-saturated part of the ground, usually following approximately the contours of the overlying land surface
well— a hole made in the earth to reach a natural deposit (as of water, oil, or gas)

—Students will draw the groundwater systems on the Oklahoma map included with this lesson.
—Students will make a key for the map of Oklahoma groundwater systems.

Science

1. Students will conduct the following experiment to demonstrate permeability.
   —Place one dry sponge on top of another in a bowl.
   —Pour water over the top sponge. Students will observe that the water seeps through the top sponge downward into the bottom sponge.
   —Leave the sponges alone for a few hours. Is the top sponge dry or still wet? What about the bottom sponge? Check the two sponges again the next day. Are they still wet or dry? Discuss what this demonstration illustrates about water in all layers of the soil. Where did the water go?
   —Place the bottom sponge in a zip-seal plastic bag. This creates a "confining layer" (making the bottom sponge an impermeable rock layer that is too dense to allow water to flow through it).
   —Pour water on the top sponge. What happens to the water?, (The water will seep downward until it hits the plastic wrap. The top sponge will become saturated, and when the water hits the plastic wrap it won't be able to seep into the second sponge. Instead, it will start flowing sideways and come out at the edges of the sponge. This demonstrates the horizontal flow of groundwater.
2. Students will work in groups to test the permeability of different earth materials (clay, sand and gravel).
   —Provide each group with a clear plastic cup, a funnel, coffee filters, a measuring cup, a pitcher of water and small amounts of clay, sand and gravel.
   —Each group will use the materials provided to design an experiment to test the permeability of the earth materials, making sure to measure the materials used and record observations.
   —Students will use appropriate graphs to record their observations and report to the class.
3. Provide clear cups, sand, clay and gravel. Students will work individually to build groundwater models, as follows:
   —Pour 1/4 inch of white sand in the bottom of the cup, completely covering the bottom of the container. Students will measure the sand to determine how much is needed to cover the bottom 1/4 inch of the cup.
   —Pour water into the sand, wetting it completely. Students will measure how much water is needed to wet the sand without leaving standing water on top. Students will record the ratios of sand to water used.
   —Students will observe that the water is absorbed in the sand but remains around the sand particles as it is stored in the ground, ultimately forming part of the aquifer.

—Students will flatten the modeling clay (like a pancake) and press the clay to cover half of the sand, pressing the clay against the side of the cup to seal off one side. The clay represents a "confining layer" that keeps water from passing through it.
—Pour a small amount of water onto the clay. Students will observe that the water remains on top of the clay, only flowing into the sand below in areas not covered by the clay.
—Place the gravel over the sand and clay, covering the entire container. Students will slope the gravel to one side, forming a high hill and a valley. Explain to students that these layers represent some of the many layers contained in the Earth's surface.
—Measure and pour water into the aquifer until the water in the valley is even with the hill. Record the measurements. Students will observe the water stored around the rocks. Explain that these rocks are porous, allowing storage of water within the pores and openings between them. They will also notice a "surface" supply of water (a small lake) has formed. This will give them a view of both the ground and surface water supplies.
—Students will measure the water level on the clay side of the cup to determine the aquifer depth.
—Provide students with soap pumps, cheesecloth or other filtering material (nylon hose) and rubber bands. Students will wrap small pieces of the filtering material around the bottoms of the soap pumps and secure them with rubber bands to keep out sand and other debris.
—Students will use screw drivers to make holes in the clay to insert the pumps.
—Students will pump water from the "aquifer."
—Students will measure the water pumped from the "aquifer." How does the water pumped from the aquifer compare with the water poured in. Students will record the numbers in ratios.
—Students will use a bottle with holes poked in it to simulate rain. Students will "rain" the same amount of water on the aquifer as that removed.
—After allowing time for the "rain" to recharge the aquifer, students will measure again to see if the same depth has been reached.
(Activity adapted from Office of Water, Environmental Protection Agency [EPA], http://water.epa.gov/learn/kids/drinkingwater/upload/2005_03_10_kids_activity_grades_k-3_aquiferinacup.pdf)

4. Students will carefully read the section in the background about the formation of the Ogallala Aquifer.
—Divide students into groups and provide each group with a large aluminum pan, gravel, sand, water and a cup for pouring water.
—Based on the reading, students will demonstrate how the

Ag Careers: Hydrologist

Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society: problems of quantity, quality and availability. They may be concerned with finding water supplies for cities or irrigated farms or controlling river flooding or soil erosion. They may work in environmental protection, preventing or cleaning up pollution or locating sites for safe disposal of hazardous wastes. Scientists and engineers in hydrology may be involved in both field investigations and office work. In the field, they may collect basic data, oversee testing of water quality, direct field crews and work with equipment. In the office, hydrologists interpret hydrologic data and perform analyses, including the use of computer simulation models. Much of the work also relies on computers for organizing, summarizing, and analyzing data such as precipitation, weather, climate, soils, runoff, groundwater levels, and water quality.

Students who plan to become hydrologists need a strong emphasis in mathematics, statistics, geology, physics, computer science, chemistry and biology. In addition, background in other subjects—economics, public finance, environmental law, government policy—is needed to communicate with experts in these fields. Communicating clearly in writing and speech is a basic requirement essential for any professional person. Hydrologists should be able to work well with people, not only as part of a team with other scientists and engineers, but also in public relations, whether it be advising governmental leaders or informing the general public on water issues.

Source: US Geological Survey Water Science School: http://water.usgs.gov/edu/hydrology.html aquifer was formed.

Math

1. Water in the Ogallala Aquifers moves downhill from northwest to southeast at a rate of 150 feet per year under natural conditions. Assuming there are no wells in between to disrupt the flow, how long would it take water from the aquifer to move from Guymon to Shattuck?
   —Students will use road maps to measure the mileage between Guymon and Shattuck.
   —Students will convert the distance from miles to feet.
   —Students will calculate the time it would take the water to move the calculated distance at a rate of 150 feet per year.
2. In the High Plains region, the total number of acres irrigated with ground water expanded rapidly after 1940, from 2.1 million acres in 1949 to 13.9 million acres in 1997. Students will solve the following problem:
   —At what annual rate did the acreage irrigated with ground water expand between 1940 and 1997?

Extra Reading

Allaby, Michael, *Droughts (Weather Science)*, Facts on File, 2011.

Chambers, Catherine, *Drought (Wild Weather)*, Heinemann, 2007. (Grades 4-6)

Ditchfield, Christin, *Water (True Books; Natural Resources)*, Children's, 2003.

Fridell, Ron, *Protecting Earth's Water Supply (Saving Our Living Earth),* Lerner Classroom, 2008.

Gardner, Robert, *Super Science Projects About Earth's Soil and Water (Rockin' Earth Science Experiments)*, Enslow, 2007.

Gifford, Clive, *Flooding and Drought (Looking at Landscapes)*, Evans Brothers, 2005.

Groundwater Foundation, *Rainmakers: A Photographic Story of Center Pivots,* Groundwater Foundation, 2005.

Kerley, Barbara, *A Cool Drink of Water*, National Geographic Children's, 2006.

Lamadrid, Enrique R., Arrellano, Juan Estevan and Amy Cordova, *Juan the Bear and the Water of Life: La Acequia de Juan del Oso,* University of New Mexico, 2008.

Ag in Your Community

Contact the Oklahoma Water Resources Board to find a hydrologist located near your school to invite as a speaker in your classroom. http://www.owrb.ok.gov/about/index.php

Online Resources

"Summary of the Water Cycle" (Includes somr helpful charts from the US Geological Survey Water Science School) http://water.usgs.gov/edu/watercyclesummary.html

"What is Groundwater?" (Excellent video from Quest Science): https://www.youtube.com/watch?v=oNWAerr_xEE&feature=youtu.be

US Map

Oklahoma Ag in the Classroom is a program of the Oklahoma Cooperative Extension Service, the Oklahoma Department of Agriculture, Food and Forestry and the Oklahoma State Department of Education.