Earth and Space Science
Aquatic Science
Environmental Systems

Aquifer Hydrology

Teacher Page

Enduring Understandings
Groundwater, like surface water, flows down-gradient. Groundwater is recharged by rain at higher elevations, and is discharged at springs at lower elevations. When groundwater comes up it becomes surface water and is a part of the hydrologic cycle. Groundwater is pumped for human use; usage and discharge lower the water table. Excessive usage can deplete an aquifer if there is no rain/recharge.

Vocabulary
Recharge, aquifer, groundwater, surface water, gradient, hydrostatic pressure, Water table, sustainability, discharge, recharge, well, Hydraulic head, Urbanization

Essential Questions:
Where does groundwater come from and where does it go?

Topical Questions:
How does water flow? And where does it go?

Objectives

- ***To describe groundwater and surface water flow.***
- ***To understand the relationships between groundwater discharge (spring flow), recharge (rain), pumping (wells), and drinking water supplies.***

Teacher Management

Estimated Time for Completion

45 min.

Materials

Liquid Soap Pump or pippette
Coarse Gravel
Clear Cup
Clear Straw (cut in two; long/short)
Clear tape
Scissors
Ruler Tray
Thumb Tack
Water
Paper Bowl or other receptacle
Food coloring (to aid visibility)

Teacher Prep

Cut straws so that one straw is the same depth as the cup and one straw is ½ depth of the cup.

Safety Considerations

This lesson uses water, caution for spills because surfaces could become slippery.

Vocabulary Building Strategies

A. Encourage students to use their lesson vocabulary words when they do their write up.
B. Have students write the vocabulary words and definitions in their science notebooks.
C. Draw a labeled watershed/aquifer diagram.

D. Word-match or fill in the blank diagram.

***Background Information for Teacher**
BACKGROUND
The Edwards Aquifer of Texas is a **karst** aquifer developed in faulted and fractured Cretaceous-age limestones and dolomites. The term karst describes a distinctive topography where underlying soluble rocks are dissolved by surface water or groundwater. Karst terrains and aquifers are characterized by distinct landforms like sinkholes, caves, springs, and an integrated system of pipe-like conduits that rapidly transport groundwater from recharge features to springs (White, 1988; Todd and Mayes, 2004). The Edwards Aquifer system lies within the Miocene-age Balcones Fault Zone (BFZ) of Texas. Hydrologic divides separate the Edwards Aquifer into three segments (Barton Springs Segment, San Antonio Segment and Northern Segment). The Barton Springs Segment of the Edwards Aquifer is the smallest and is the focus of this activity. Figure 1 shows the 3 zones of the Bartons Springs segment. The journey of rainwater flowing to Barton Springs begins in the contributing zone-the area that contributes water over the land to creeks that feed the aquifer. The **recharge zone** is characterized by sinkholes, faults, fractures and caves (figure 2) where rainwater feeds the aquifer. The final zone of the Barton Springs Segment is the Artesian or Confined Zone. In this area the aquifer is capped by clay or shale so the groundwater below is under pressure.

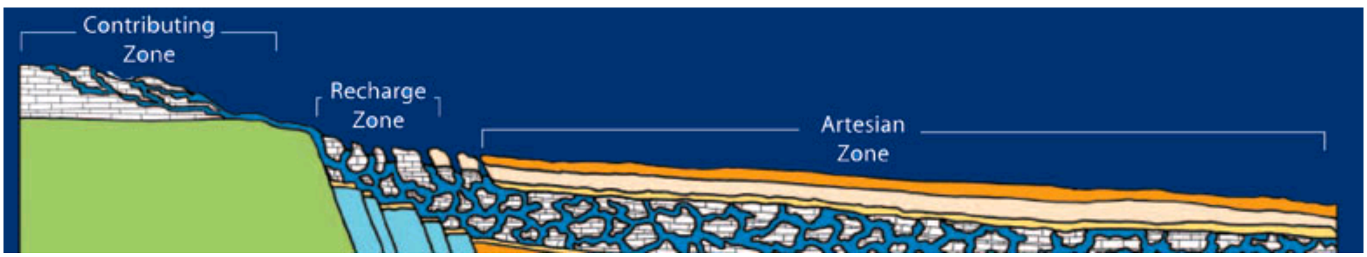


Fig 1. Three zones describing watershed topography, recharge and the aquifer.

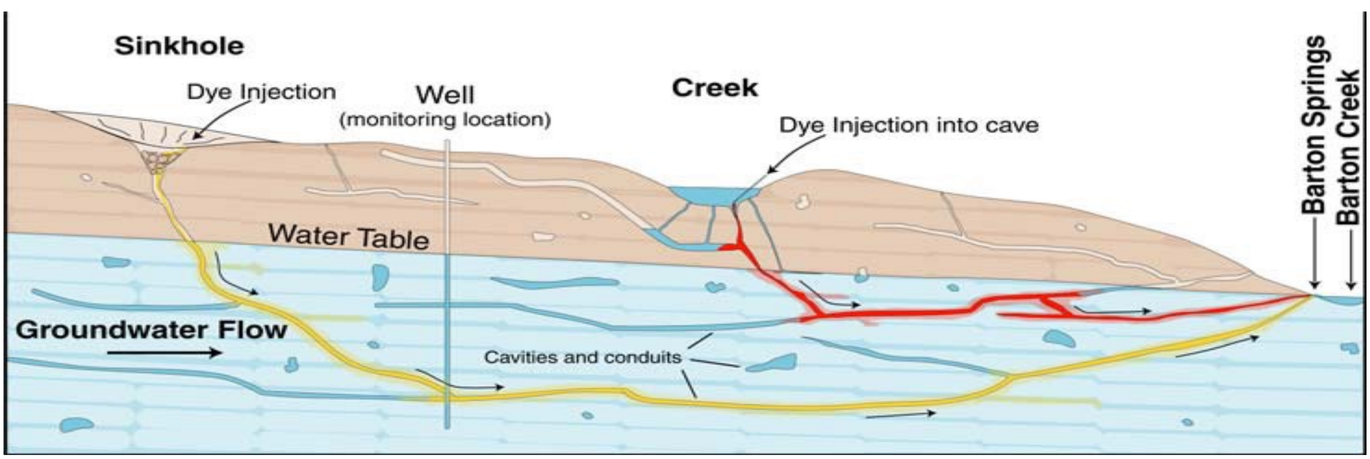


Fig. 2 Karst features and Groundwater flow

Misconceptions
1. Groundwater flows in underground rivers.
    a. The majority of underground flow happens through rock fractures, and connected pore spaces not open underground channels.
2. Groundwater and surface water are separate and do not interact.

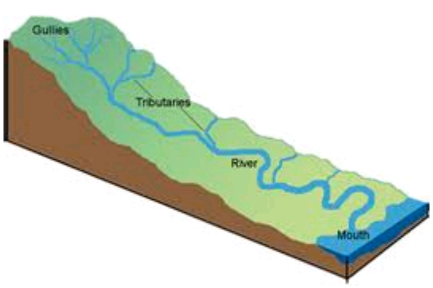
a. Groundwater reaches the surface at springs and is incorporated into creek/river flow. Thus, it becomes surface water, and surface water evaporates to join atmospheric water which recharges groundwater, and streams as rain (meteoric water). This is referred to as the hydrologic cycle.

3. Groundwater is not a renewable resource.
    a. Ground water is a part of the water cycle, and thus can be renewed through a process called recharge. However, some aquifers hold water that is thousands to millions of years old (fossil water)! These aquifers' (such as the Ogallala) recharge can happen at such a slow rate, that on human scale they could be considered non-renewable.
4. High pressure from water quantity moves groundwater through aquifers.
    a. Hydraulic head (the sum of elevation and water pressure divided by the weight density of water) determines the lateral and vertical driving force of water in an aquifer at a particular point. Groundwater, like surface water, moves down gradient; from areas of high pressure to areas of low pressure. So, simply speaking, groundwater is moved by gravity.

Probing Questions
*See student sheet.

Focus Activity/Warm up
Show part ___ of groundwater video.

Note:
*The lesson is set up so in the following outline: simple concept (engage), abstract application of concept (explore), concrete application of concepts (elaborate), and human application/connection to concepts discussed (explain, evaluate and elaborate).



Engage
Hold up a tray creating a slope at the top and slowly pour water down the tray.
Teacher (T): What happened?
Students (S): The water went down the tray.
T: Right! So, water flows down-gradient; from high elevation to low elevation. In other words, water flows down-hill.
-Do you prefer to ride your bike up-hill or down-hill? –why?
S: Down! Because it's easier.
T: Right, because it takes more energy to ride up-hill. When you're going down, the height and the steepness (gradient) of the hill (slope) provide you with energy: Potential Energy. Water is the same. It would rather go down –hill because it takes less energy. It is hard work to go up-hill and water is lazy. Is it always the case that water flows down hill?
S: No! The water goes up the slide at Schlitterbahn!

T: True, it is able to go uphill because the water is under pressure; it has been given extra energy. Without that external force, would the water go up-hill?
S: No.
T: Right. What about groundwater? Does it flow down-gradient? Why?
S: Yes; No…it doesn't matter where it is, it's still lazy; its different because it is underground and those rules do not apply.
T: Let's explore that idea. I am giving you a potentiometric map (a map that measures the potential energy of the water at a point; the height of the water table) of the Edwards Aquifer.

Explore

Students will construct a plastic cup aquifer model to model natural spring flow, recharge, pumping and wells.

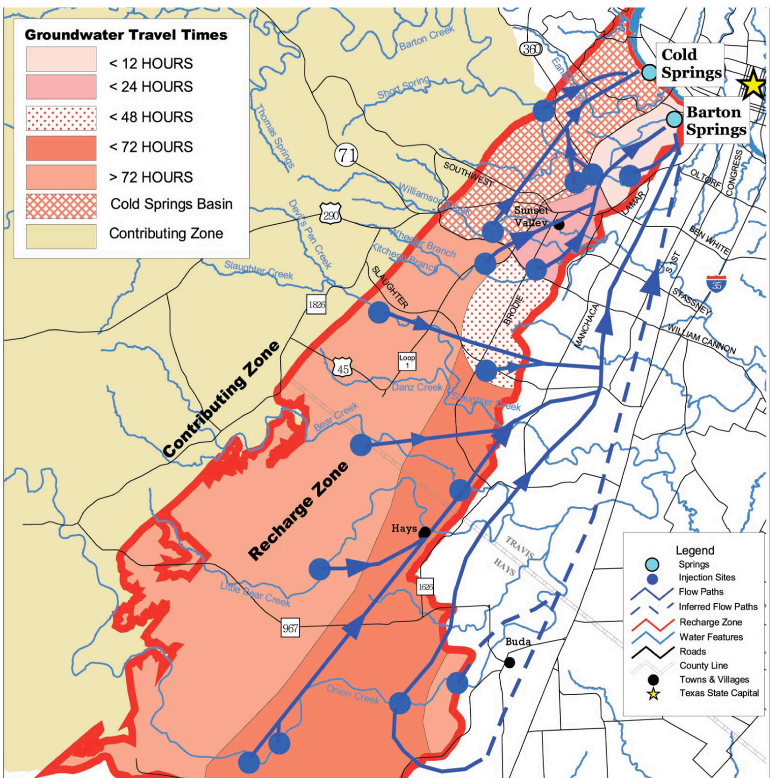
*See Student Sheet

Focus question: How is groundwater connected to people and Barton Springs?
Provide materials to groups of 4-5 students/model (5 set-up steps).

Explain

Discuss worksheet answers

Elaborate



Trace injections: A joint study between the City of Austin and the Barton Springs/ Edwards Aquifer Conservation District

Show map of Dye Trace Study and discuss…

Show the map of the dye trace study. Point out the injection points at recharge features and discharge at wells and springs. Point out the injection point closest to your location and discuss which spring it flows to and how fast it flows. Hydrogeologists flush non-toxic dye into caves and sinkholes in the recharge zone to determine flow paths and rates of groundwater flow. They put receptors in various wells and springs throughout the area to detect the dye. They found that water flows through its underground passages surprisingly quickly compared to other aquifers (1 mile in 1 year). For example, water traveled the nearly twenty miles from Onion Creek near Buda to Barton Springs in as little as three days. Most water re-emerged at the four Barton Springs outlets, but some pathways in the aquifer flowed to Cold Springs on Town Lake. An average of 50 million gallons of water a day resurfaces from the aquifer at Barton Springs.

Evaluate

Students should answer the activity probing questions in the Aquifer Model Student Sheet.

*See student Sheet "Aquifer Hydrology"

Closure/Daily Assessment

If students have not completed the activity probing questions in the Aquifer Model Student Sheet, they should complete them as homework.

*Appropriate clean-up TBD by teacher.

Extensions:

1. **Physics:** Teacher could chose to make two springs, at higher and lower elevation, by punching an extra hole with a thumb tack at a higher elevation. This allows you to discuss the fact that springs at higher elevations, higher in the watershed, will stop running before springs at lower elevation.
2. **Social studies:** You can double the population in the model by adding an extra pump. Discuss the effects of increased population and pumping. Also talk about development and how that affects recharge.
3. **Math:** Calculate the rate of water depletion when pumping is added. Or calculate change in water table after pumping, then natural flow over a set amount of time, and find the difference.
4. **Art:** Draw the hydrologic cycle including groundwater in aquifers.

Differentiation TBD

References:

- Background and Maps courtesy of the Barton Springs Edwards Aquifer Conservation District

  2007 report, Potentiometric Flow Maps…
  http://www.bseacd.org/uploads/AquiferScience/HR_PotMap_BSEACD_2007.pdf

- http://www.idahogeology.org/services/Hydrogeology/PortneufGroundWaterGuardian/my_aquifer/vocab/vocab_text/hydrhead.html
- EPA Water-Sourcebooks-Grade-Level-9-12

Aquifer Hydrology
Student Sheet

Aquifer Model: Building Procedure.
1. With a thumbtack, poke a single hole into the bottom side of the clear plastic cup. Do NOT remove thumb tack.
2. Place cut straws into cup (at least 1 cm apart) and tape to inside wall of cup
3. Place soap pump (or pipette) into cup
4. Fill cup 2/3 full with gravel.
5. Fill cup ¾ full with water.
6. Place model in pan or larger container to catch drainage

From what you learned from the video, draw and label the model with the following terms:

- ☐ **Deep and *shallow wells***
- ☐ ***aquifer rock***
- ☐ ***water table***
- ☐ ***pump***
- ☐ ***spring***
- ☐ ***rainwater***

Remove the thumbtack from your model (make sure the model is in a pan) and observe
Answer the following questions about the model:

1. In an aquifer, water discharges into a spring
   a. Which part of the model mimics a spring?

2. Is the model spring flow constant? Why?

3. What happens to the drip when the water level is low?

Refill your aquifer with water (leave spring unplugged):

4. What does refilling your aquifer model represent?

5. How did refilling the aquifer effect spring flow?

   a. Is there a relationship between water level in the aquifer and spring flow?

6. In the model what factors are affecting spring flow rate?

Plug your spring (with thumbtack) and refill model. Observe the wells (clear straws).

7. What happens to the water level in the wells as the aquifer water discharges without recharge?

8. Which well ran out of water first? (long straw=deep well; short straw=shallow well) Why?

Plug your spring. Observe water level in straws as you BEGIN PUMPING water out (use soap pump or pipette).

1. What happens to the water table in the model?

   a. Would you expect this to happen in a real aquifer?

2. Who would be most affected by continued pumping without recharge?
    a. Person with deep well
    b. Person with shallow well

3. Explain your answer.

Refill aquifer. Allow spring to flow, and allow pumping.

1. Describe the interaction between spring flow and pumping according to your model. Does this seem reasonable? Why?

2. How did the sum of pumping and natural discharge effect water supply for your straw wells?

Conclusion:

In your experiments with the aquifer model, you modeled natural discharge in aquifers at springs. This is a vital process for many aquatic organisms. You also modeled the effects of pumping ground water and saw that pumping may speed up the depletion process. If the water in an aquifer is lost faster than it recharged, the aquifer could dry up.

a. How is it that Barton Springs is able to flow continuously?

b. How would flow conditions vary under drought conditions?

Ground water is a part of the water cycle, and thus can be renewed through a process called recharge. However, some aquifers hold water that is thousands to millions of years old (fossil water)! These aquifers' (such as the Ogallala) recharge can happen at such a slow rate, that on human scale they could be considered non-renewable.

c. Is the Edwards aquifer an example of a renewable or non-renewable source? Support your answer.

d. If you could design policy for sustainable usage of groundwater, what would it be?

According to the Texas Parks and Wildlife Department the population in the Hill Country area (Central Texas) is expected to grow 70% by 2050. As population increases, so does the demand for water. However, if you live in the Austin area the bigger threat to the aquifer from growing population is development over the recharge zone.

1. How could this be a problem?

2. Our population is growing, but aquifer recharge happens at relatively the same rate (largely depending on climate). What would have to change about human behavior in order for the supply to meet demand?

3. Barton Springs is home to many aquatic species. Among these, the Barton Springs salamander (an aquatic amphibian). The Barton Springs salamander is endemic to Barton Springs and it is listed as an endangered species. How may urbanization (development), population growth, and drought effect the survival of this species?

Barton Springs Dye Trace Study

Number	Dye Input	Miles Traveled	Arrival Time Days/Hours
1	MO-PAC Bridge	3.2	5 Days
2	Mount Bonnell Fault	2.7	5-6 Days
3	Dry Fork Sink	4.5	1 Day
4	Whirlpool Cave	5.5	3 Days
5	Westhill Drive	1.8	10 Hours
6	Brush Country	5.2	8 Days
7	Brodie Sink	7.4	1-2 Days
8	Midnight Cave	8.3	7-8 Days