Exploring Aquifers Lesson Two:
"**Water Flow in Aquifers"**

Academic Questions: How does water move through an aquifer?
What ways does water enter and leave the aquifer?
How much time does water spend in an aquifer?

Objective(s):

- To understand the movement of water through an aquifer
- To understand how and why water storage in an aquifer changes over time

Key Terms: cohesion, adhesion, capillary action, Pascal's principle, Bernoulli's principle, buoyant forces, specific gravity, diffuse recharge, discrete recharge, sinkholes, losing streams, well pumps, artesian wells, residency time
Click here for definitions to Exploring Aquifers vocabulary.

Process (Activities):

1. This lesson explores the properties of water that affect its movement and behavior. Some of the properties and principles that come into play in the movement of water into and through aquifers are; capillary action, cohesion and adhesion of water molecules, water pressure, Pascal's principle, and Bernoulli's principle. The buoyant force, and the specific gravity of water and saline waters are involved in the boundaries between freshwater and saline waters in aquifers. Students will work with materials and water to understand the laws governing the movement of water.

   Before you begin, gather the following materials:
   - containers
   - salt
   - foil
   - waxed paper
   - a glass
   - tennis tube cans
   - water jugs
   - toothpicks
   - metric stick
   - window fan (for exploring Bernoulli's principle)
   - spring scale
   - graduated cylinders

2. Working in small groups, have students explore the principles of water by creating a water maze that gets the water to move sideways, move up, speed up, form laminar sheets (smooth thin sheet of water) or turbulence, stick together, and push past obstacles. Hand out the Water Action Fact Sheet.

3. Ask students to relate the water movement in their maze to the water movement in their aquifer models.

4. After the students have completed their maze experiment, explore with them how water gets into the aquifer in the first place. Allow students to brainstorm about how water enters an aquifer. Explain to the students that water enters the aquifer and is called recharge. Recharge occurs when streams and rivers cross the permeable formation and go

underground or when precipitation falls directly on the outcrop of the permeable formation. Some recharge of groundwater happens when water seeps and oozes through the subsurface and other recharge of groundwater occurs through a vast network of localized openings that are able to rapidly transport both water and contaminants. Water that seeps and oozes through the subsurface is called diffuse recharge. That water which flows through localized openings is called discrete recharge. Some recharge features include:

- Sinkholes, which are large openings in the land's surface from dissolution of karst that have underground drainage. Sinkholes provide direct connection between surface water and groundwater. Erosion by ground water produces karst topography characterized by sinkholes, caves, and disappearing streams.
- Losing streams, which are surface streams that contribute water to the karst groundwater system in localized areas. These streams are typically a dry gravel streambed most of the year, except after major rainfall.

5. Ask students to brainstorm how water exits an aquifer. Explain to students that water exits aquifers by well pumps or in artesian wells and springs. Well water exits the aquifer by hand or electric pumps. Artesian wells and springs exist where the sheer weight of new water entering the aquifer puts pressure on the water deep inside the aquifer. This hydrostatic pressure forces water up to the surface through faults, and wells. Artesian water is water confined under pressure like that in a pipe. It occurs in permeable beds bounded by impermeable formations.

6. Wells are often the preferred source of drinking water, when compared to surface water. This is because it is closer to much of the population compared to water found in streams, rivers and lakes and because the water quality is usually higher because of filtration and natural purification processes.

   Allow students to explore how pumps bring up groundwater with the following experiment. Use these materials: food coloring, tall clear glass, long clear straw.
   a. Fill a tall clear cup with colored water. Lower a clear straw into the water and cover the end with your thumb. Bring up the straw with the water column inside.
   b. To build the water column higher, which is what happens inside a pump, quickly lower the straw back into the cup, with your thumb off the top. Cover the top of the straw and pull up quickly.
   c. Get a rhythm going, and practice making an airtight seal with your thumb. You may not be able to actually have water come out of the top of the straw because the airtight seal is hard to maintain, but you should be able to see the water column mounting taller inside the straw.

7. Allow students to construct a demonstration of artesian springs to compare to the water movement by a pump with the following experiment.
   a. Begin by gathering the following materials: disposable plastic container with tight lid, hard straws or plastic tubing, flexible tubing, small funnel to fit inside tubing, modeling clay.
   b. Cut the hard tubing or straw one fourth of the length of the straw. Make two small openings in the lid of the container and put in straws.
   c. Press modeling clay around the base of the straws where it is inserted into the top to make the joints air and watertight.
   d. Fill the container with water and put on the lid.
   e. Attach the tubing to the taller straw piece and attach a funnel to the tubing.
   f. With the container on a waterproof surface, hold the funnel above the container. Pour water into the funnel. The water goes into the container and pushes water out of the

lower straw. This water is acting as an artesian spring, with the tall column of water inside the flexible tube pushing the aquifer water in the container by hydrostatic pressure.

8. Discuss with students how fast water flows in aquifers. Water movements in aquifers normally range from 1 meter per day to 1 meter per year. Karst or carbonate aquifer groundwater travel rates are often 1 mile per day, while nonkarst are a few feet per year. Dye tests indicate travel time for water from a single point can be variable and can exit from multiple springs and wells. A complex flow system is guessed at by using information from wells and dye tests.

9. Ask students to compile a list for each major aquifer of the average length of time water spends underground. This residency time for water in the 9 major aquifers of Texas varies greatly. After obtaining area estimates and holding capacity for aquifers (See Lesson One, Activity Two), have students estimate travel distances across the entire aquifer for the most distant points of recharge and discharge. Using the rough estimate of 1 mile per day for carbonate and 1 foot per year for sand and gravel aquifers, students get a rough idea of the age of underground water in the state of Texas.

Product/Application: Ask students to create an authentic aquifer water discrete recharge feature (losing stream or sinkhole) and add it to their maze as well as an authentic method for water to exit their maze (a pump or artesian spring). Once students have successfully made these modifications to their water maze, challenge the groups to a race. What group can output a cup of water from their maze in the least amount of time? Have student calculate the water flow rate and residency time of the water in their maze.

Assessment/Evaluation: Ask each group to identify the different principles or property of water within their maze and how these work together with an aquifer. Ask students to look at the aquifer models and predict the movement of water through the model features. Ask students to label areas with properties or principles that come into play during water movement through their aquifer model. Finally, ask students to estimate the time of travel for water entering their aquifers on their birth dates.

Conclusion: Ask students to find the total water discharged from and recharged into the aquifer upon which their model was based. Label the model with the amounts of water entering and leaving the aquifer for the most recent year.

Resources:
Fluid Mechanics Hall of Fame:
http://mech.postech.ac.kr/fluidmech/history/

Fluid Dynamics
http://home.earthlink.net/~dmocarski/chapters/chapter7/main.htm

Highlights in the History of Hydraulics: If you've got about an hour to learn some history this site is great. It has short biographies of just about all the scientists who have contributed to our understanding of fluids and forces.
http://www.lib.uiowa.edu/spec-coll/Bai/hydraul.htm

Water Science for Schools Ground water: Wells
http://ga.water.usgs.gov/edu/earthgwwells.html

Time Frame: Two 45 minutes class periods.

Grade Level: 6th-12th

TEKS Correlation:
Science
Grade 6: 6.1, 6.2, 6.3, 6.4
Grade 7: 7.1, 7.2, 7.3, 7.4
Grade 8: 8.1, 8.2, 8.3, 8.4
Aquatic Science: 4.B, 8.D, 10.A,B,C,
Environmental Science: (b)1, 4.B,C, 5.B,
Geology, Meteorology, and Oceanography: (b)1, 10.A

Mathematics
Grade 6: 6.1, 6.8, 6.11, 6.12, 6.13
Grade 7: 7.3, 7.4, 7.9, 7.13, 7.14, 7.15
Grade 8: 8.5, 8.14, 8.15
Geometry: 6
Precalculus: 2

Technology Applications (Computer Literacy)
Grades 6-8: 2, 4, 5, 7, 8

Social Studies
Grade 6 6.21, 6.22, 6.23
Grade 7 7.8, 7.21, 7.22, 7.23
Grade 8 8.10, 8.30, 8.31, 8.32

English
Grade 6: 6.1, 6.2, 6.5, 6.13, 6.17, 6.20, 6.22, 6/24
Grade 7: 7.1, 7.2, 7.5, 7.13, 7.17, 7.20, 7.22, 7.24
Grade 8: 8.1, 8.2, 8.5, 8.7, 8.10, 8.13, 8.17, 8.18, 8.20, 8.22, 8.24
English I: 1, 4, 6, 8, 13, 15, 16, 21
English II: 1, 4, 6, 7, 8, 13, 15, 16, 21