Environmental Science Institute
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**Groundwater: The Hidden Resource**

Lesson plan for grades 6-8
Length of lesson: 2 X 60 Minutes Sessions
Adapted by: William Oakley, Environmental Science Institute, Dec. 4, 2012
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**SOURCES AND RESOURCES:**

- **Georgian Court University Aquifer lesson Plan: http://gcuonline.georgian.edu/wootton/groundewateraquifer.htm**
- **Dr. Jay Famiglietti's Hot Science – Cool Talks Lecture: "Last Call at the Oasis: Will there be Enough Water for the 21st Century?" October 26, 2012, UT Austin: http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks/last-call-at-the-oasis-will-there-be-enough-water-for-the-21st-century**
- **GRACE Satellite website: http://www.csr.utexas.edu/grace/**
- **Definition of Climate Change used http://nsidc.org/arcticmet/glossary/climate_change.html**
- **Aquifer information source, USGS http://ga.water.usgs.gov/edu/droughtandgw.html**
- **Flood concept information from UNSW Australia http://www.science.unsw.edu.au/news/major-floods-recharge-aquifers**

**POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON (see Intern Excel File for URLs):**
**§112.18 b: 1AB, 2AB, 3ABCD,**
**§112.19 b: 1AB, 2AB, 3ABCD, 8C**
**§112.20 b: 1AB, 2AB, 3ABCD,**

**PERFORMANCE OBJECTIVES :**
Students will be able to:

1. Visualize the relationship between aquifers and the water cycle; specifically water storage and movement underground
2. Investigate Explain how aquifers are affected by drought and flood

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3. Relate how the aquifer system and ground water concepts to their lives

**MATERIALS (per group):**

- Access to internet or download of groundwater video
- Large, transparent Tupperware container, fish tank or other water tight containers. *For the second part of this lesson a removable drainplug must be installed on the container*. You need a container for each demonstration used. Groups will consist of ten students each, and one per group. The second half of the lesson is a crucial part, where the students examine the extreme conditions affecting the aquifers. Depending on resources, you can do a minimum of 2 aquifers (one for drought one for wet) or up to four (the maximum the lesson accommodates for)
- Sand
- Modeling clay
- Gravel
- Green fabric
- Water in squirt bottle
- Turkey Baser (one extra for drought team)
- Food coloring
- Stopwatch
- Large Graduated Cylinder or Beakers

(Note, this lab will use multiple run-throughs so it the amount needed depends on class size, so this resource list does not have a recommended quantity. It's best to read through the lesson first as specific quantities are used and then calculate how much you need based on size and # of runs)

**CONCEPTS:**

An **aquifer** is a body of saturated rock through which water can easily move, and is an important part of our drinking water supply. Aquifers store water and are the source of well water. There are many different ways to classify aquifers. This lesson focuses on confined and unconfined aquifers. Aquifers are capable of filtering water because the water passes through spaces inside the rock. The following definitions will be used in the lesson and the Teacher should become familiar with them. (Taken from original source)

1. The amount of pore space present in rock and soil is known as **porosity**.

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2. The ability of fluids to travel through the rock or soil is known as **permeability**.

3. The permeability and porosity measurements in rock and/or soil can determine the amount of water that can flow through that particular medium. A "high" permeability and porosity value means that the water can travel very quickly, but means it is not as filtered.

4. Ground water can be found in aquifers. An **aquifer** is a body of water-saturated sediment or rock in which water can move readily.

5. There are two main types of aquifers: **unconfined and confined**.

6. An **unconfined aquifer** is an aquifer that is exposed to the surface of the land. Because this aquifer is in contact with land, it is impacted by meteoric water and any kind of surface contamination. There is not an impermeable layer to protect this aquifer. It is also where new water can enter or "**recharge**" the confined areas of the aquifer

7. A **confined aquifer** is an aquifer that has a confining layer that separates it from the land surface. This aquifer is filled with pressurized water (due to the confining layer).

8. Porosity and permeability of the sediment, soil, and bedrock in the area also affects the **recharge** rate of the ground water. This means that in some areas, the ground water can be pumped out faster than it can replenish itself. This creates a number of problems

**Drought:** A drought is a prolonged period of abnormally low precipitation. This isn't just a few days or even a week, but lasts for months. When the rain levels are low, the amount of stored water decreased over time (in lakes, reservoirs, aquifers, etc. So aquifers suffer a double blow: they are drained faster for water usage, while the lack of rain prevents them from being replenished. Worse case scenario the aquifer can run completely dry. Groundwater merely refers to the water that is in the ground, like in the aquifer.

**Flooding:** . Specifically there are multiple types of flooding according to FEMA, for purposes of the lesson we will use the flash flood example. In flash flooding, rain falls in heavy considerations and quickly fills up all surface water storage areas such as lakes, aquifers, etc. While flash floods are quite devastating on the surface, they do have a bright side: they can substantially refill aquifers.

**Climate Change:** "A study dealing with variations in climate on many different time scales from decades to millions of years, and the possible causes of such variations.1) In the most general sense, the term "climate change" encompasses all forms of climatic inconstancy (that is, any differences between long-term statistics of the meteorological elements calculated for different periods but relating to the same area) regardless of their

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statistical nature or physical causes. Climate change may result from such factors as changes in solar activity, long-period changes in the Earth's orbital elements (eccentricity, obliquity of the ecliptic, precession of equinoxes), natural internal processes of the climate system, or anthropogenic forcing (for example, increasing atmospheric concentrations of carbon dioxide and other greenhouse gases). 2) The term "climate change" is often used in a more restricted sense, to denote a significant change (such as a change having important economic, environmental and social effects) in the mean values of a meteorological element (in particular temperature or amount of precipitation) in the course of a certain period of time, where the means are taken over periods of the order of a decade or longer."

**BACKGROUND:**

This lesson is inspired by on Jay Famigietti's October 26, 2013 *Hot Science – Cool Talks* lecture, and structured around the Georgia University Aquifer Lesson.

Please note that the Hydration Cycle is a more complete version of the water cycle that is normally taught in elementary school, as it includes groundwater in the mix.

As defined earlier (specifically definition 2), climate change is a differentiation from the average weather phenomena that can cause a significant impact. As the lecture describes, the GRACE satellite can be used to monitor the flow of water in various regions. And the GRACE data shows a disturbing trend: Wet areas are getting wetter while dry areas are getting drier. This trend matches definition 2 of climate change, so we're dealing with a phenomenon that poses a great threat to the survival of humanity in the coming decades.

Droughts are a huge burden on Aquifers: the lack of rain prevents aquifers from recharging while the rate at which water is drawn/pumped from the well increases due to the lack of water on the surface. If dry areas continue to get drier, then drinking water will become extremely scarce. Already there are areas around the world where people have to walk a mile or more to get water, and if the dry conditions worsen in volatile areas, we could be looking at massive wars. Conversely, if wet areas are getting wetter, flash floods will become a bigger problem. Imagine if all of New York was hit with a massive flood at once, worse than Hurricane Sandy, that's how bad things can get in the years to come.

The lesson is divided into two parts: The first allows the students to build their own aquifers in order to explore how they work, and how they affect us. This will set up the framework for the second half, where a deeper analysis of what happens.

Minute Marks for suggested clips from Jay Famiglietti's *Hot Science – Cool Talks* lecture (linked in SOURCES AND RESOURCES section):

26:00 to 26:36 (Grace Satellite summary)

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30:30 to 32:08 (Example on how it works)
40:00 to 42:21 (A very good clip, introduces "wetter getting wetter, dryer getter dryer" concept)

**PREPARATION:**
It is helpful if the teacher sets up the plastic tubs and aquifer simulations and performs some of the water simulations in advance of the class. This way, they can demo the simulations during the ENGAGE section to explain basic concepts behind the water cycle (Precipitation, percolation, storage/movement of water underground)

The Teacher should watch the Jay Famiglietti to describe the GRACE Satellite System so they can explain how it is used to detect where water is and how this affects us.

**ENGAGE:**
Ask students what they remember about the water cycle, and what they know about aquifers to get them interested. Then show students the following video: http://www.youtube.com/watch?v=lhGzZcJftBw

This one can also be played, though it has all the elements that will be discussed in the lesson, so you can link back to it later: http://www.youtube.com/watch?v=fAyEUblMLUA

"So how is the water cycle different from the hydration cycle?"

"What is the difference between evaporation and precipitation?"

"Do you know what an aquifer is?

Depending on students' answers, teachers can elect to demo some of the aquifer simulations using what they constructed in advance of teaching the lesson. This way they can physically illustrate various parts of the water cycle if necessary.

**EXPLORE:**
(NOTE: This activity is designed to be done in step by step format, but it is possible to review all instructions first and then let the students work at their own pace. This is left up to the discretion of the teacher)
There should be two or three groups, and in the end each group will perform a different task, one group will model a drought, the other a flood. If there is a third group, they may try a variation of the drought or flood. The initial construction of the Aquifers are the same for each group though and will happen at the same time. Each student should perform of the tasks listed in the lettered steps below so everyone can participate.

Also, students will be modeling a lake basin in addition to the aquifer, so it may help in advance if there is a designated lake area so there are no issues during the lesson.

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Each group will have the students gather around the materials and each student will do one of the steps as described:

a. Student 1: Pour ¼ inch of white sand on the bottom of the container

**Teacher explains:** That sand represents an **aquifer**. Aquifers can be made of many different types of materials from the earth. For purposes of this activity, it will be made mostly of sand and gravel. Because the material within such sediments has lots of spaces, they can hold lots of water. Normally the water would keep on running through such sediments because there's nothing to hold them in the spaces, but often the sand sits on a later of **bedrock** which won't let the water sink in any further (like the bottom of the container holds the water, preventing it from running out onto the desk and all over the floor!). The water can move horizontally within the sand, so if the sand layer is on a slope the water will run downhill through the spaces, but it can't sink any further vertically because of the rock layer below. When all the spaces between the grains of sediment are filled with water, we say that the layer is "**saturated**" with water. The top of the saturated layer is termed the "**water table**". On wet years the water table will be quite close to the surface, whereas in drought years you would have to go much deeper to find saturated sediments and the water table will thus be much deeper (lower). We will investigate this later in the lesson."

b. Student 2: Pour water into the sand only to wet it, *IT IS IMPORTANT* for this exercise that student not fill the water up past the sand.

**Teacher will explain:** The water being poured demonstrates how the sand particles can hold the groundwater forming the aquifer.

c. Student 3: Flatten the clay into a pancake large enough to cover about 2/3 of the sand layer. Press the clay against three sides of the container to keep about 2/3 of the sand sealed between the container below and the clay above. Against one side of the container, students can form an bowl-shaped area that fills in with water to form a "lake".

**Teacher will explain:** The clay is the "confining layer" that often sits on top of an aquifer and prevents new groundwater from entering the aquifer in this area. Areas where there is no "top" on the aquifer are called "**recharge**" areas because water here can get into the aquifer. The bits of the aquifer with rocks above and below them are termed "**confined**" aquifers

d. Student 4: Push a syringe or turkey baster through the clay and into the sand on the "confined" side of the container.

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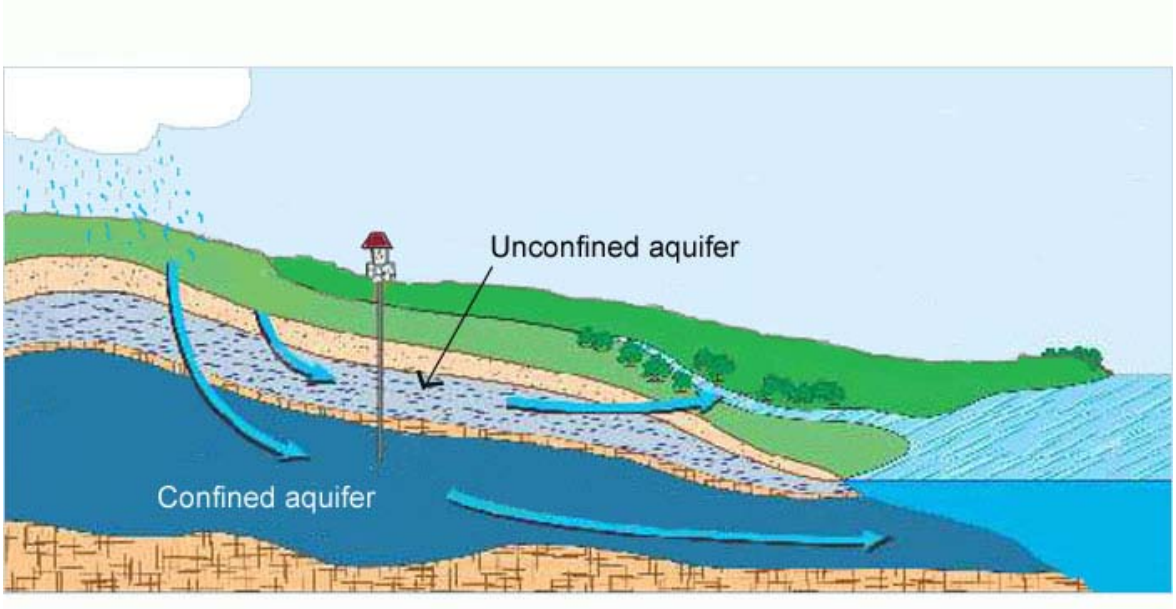
**Teacher will explain:** This represents the "**bore hole**" or deep well from which many utility companies pump water out of aquifers to provide the inhabitants with their water for their homes and businesses.

e. Student 5: Place a second layer of sand on top of the clay.

**Teacher will explain:** The second layer of sand represents the unconfined portion of a second aquifer which is again collecting groundwater. In some areas there are 2 or 3 different aquifers and different depths, each representing a layer of "porous" rock or sediment (like sand) separated by layers of solid rock (http://water.usgs.gov/ogw/aquiferbasics/uncon.html). A hole dug into this unconfined aquifer is called a **well**, and that well will fill with water, just so long as there is water in between the grains of the aquifer sediment in the areas near the well.

f. Student 6: Place fine grained aquarium rocks so that they cover both the sand and clay.

Teacher will explain: The top layer is the layer one we usually see and call "soil". Because this soil is porous, groundwater flows through it (infiltrates it) and flows into to lower layers of earth. The top layers of soil usually contain some water, but also have many empty spaces between soil grains. Such soil is termed "**unsaturated**". Only if all the areas of soil below it are so full of water that the newly arriving rain has no place to go would this soil become "saturated" and this would usually not last for long after the rain stopped and the water starts to drain away. See diagram below (or show the class) for a better understanding.



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g. Student 7: Tip the model with the end with the "constrained aquifer" (with the baster in it) toward the bottom of the slope (take care to do this without knocking the baster over).

**Teacher will explain:** This represents the typical slopes of hilly or mountainous areas

h. Student 8: Place a thin piece of green porous fabric over top of the model.

**Teacher will explain:** This represents the plants growing on the soil surface.

i. Student 9: Slowly pour (3 cups of) water on the top of the hill while the rest of the students watch where the water runs, down the hill, into the rocks, sand and clay as well as forms a "lake" on side of the container.

j. Student 10: Squeeze the bulb gently while supporting the tube (so it doesn't pull out) and allow the it to relax. Water is intended to come up the tube.

**Teacher will explain:** This models what happens when your local water utility uses the bore hole and pump to obtain the water you use in your home and yard (the water is often stored in water towers within the township).

a) Discard the remaining water siphoned from the turkey baster. Allow the aquifer simulators in the plastic tubs to dry overnight.

**First 60 minute session ends here.**

**Second 60 Minute session begins:**

**EXPLAIN:**

The second part of the lesson explores what happens to an aquifer during extreme conditions. To model what happens, have the students follow these instructions:

*Flood versus Drought Groundwater* ***Simulation and Measurement****:*

1) Have a "Flood group" "pre-wet" their aquifer by pouring in 1.5 cups of water and allowing it to permeate the various layers. Allow any excess water to drain out the drain hole in the bottom of the container.
2) Have a "Drought group" take their fully-dry aquifer from yesterday, and unplug the drain hole in the bottom of the container.
3) Have both groups pour 3 cups of water into their aquifer simulations, with the drain holes unplugged. Have them use the stopwatch to record.
    a. The amount of time it takes for water to run through the system (stop the watches after water stops dripping from the drain hole).

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b. The amount of water that drained through each aquifer. Compare the resulting water amount and clarity from the "pre-saturated" aquifer versus the "dry" aquifers.

After the containers used in the simulations have drained completely, they can be used again to make visual comparisons of what happens during flood and drought conditions.

*Flood versus Drought Groundwater Flow* ***Visual Comparison****:*

1) Both teams need to fill their aquifer with 1.5 cups of water by pouring the water slowly over the constructed hill. This will allow the aquifer to start with some water in it to simulate a real life aquifer being used, and eliminate any performance differences from the previous simulation. Drain plugs should be kept in place.

2) The "flood team's" goal is to simulate a flash flood in the area. 3 Cups of water should be poured from the hill at a steady rate, not too fast but not a slow trickle. The group should observe how long it takes the aquifer to flood and carefully observe any changes within the layers of the container:
    a. Does the flow rate increase during the heavy flooding?
    b. Does the surrounding rocks/sediment mix with the water?
    c. Are there any paths being carved on the surface layer?
    d. Ask students to describe how the flooding affects the confined and unconfined layers.

3) Simulating the drought conditions (water draw-down) requires a completely different approach. Have the students fill the tank with 3 cups of water poured slowly like in part 1. If that is not enough keep pouring until the lake is full. To simulate a drought, have the students take a spare turkey baster. Suppose that one full turkey baster is the equivalent of one full month of water supply. The student group should use the lake first and the aquifer second at first (75%/25%). The students should then see how long they can go without completely draining the lake completely, motivating them to start using the aquifer reserve more. Have them observe how quickly this uses up the aquifer reserve. If available, you can use a hair dryer to simulate prolonged heat/drought (a year or more) and then let the group pour 1.5 cups of water. They can then observe what happens to the layers in the container:
    a. Does the water flow between layers as quickly as it did before?
    b. Does the lack of water keep the "lake water" in place?
    c. Does the drought cause a major shift in the confined and unconfined layer topography?

Let each group pick a representative and have them report what they saw, using the probing questions suggested above.

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**ELABORATE**

After the discussions, use the doc-cam to show the students the GRACE website. Briefly explain to them that GRACE is a satellite system that operates off of changes in the Earth's gravity field that are caused by things like large bodies of water existing underground. It is important to note that the satellite only tracks the changes in water in a large area, so it is limited in certain aspects.

> It is recommended to play clips from the video (the ones recommended before) to help give the students a feel for the satellite system, how it works and the dry areas getting drier and the wetter areas getting wetter. The link provided will link you directly to the lecture, however you will need internet, so it's best to just use a projector/doccam to show everyone at one time.

Let students guess where they think potential flood and drought areas are and show them images from GRACE. This information starts at minute mark 26:33 and ends at 27:43.

To finish things off, I have the class discuss the possible problems of this trend, and what can be done to prevent it.

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**EVALUATE**:

SESSION 1:

The teacher can give a short post-assessment questionnaire (After Day 1):

Name:_____

Date:_____

1) What is an Aquifer and how does it play a role in the Water Cycle?

2) What are the two major classifications of Aquifers and what are the differences?

3) Is there a difference between a Saturated an unsaturated area?

4) What purpose do humans use Aquifers for?

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SESSION 2:
The teacher can give a short post-assessment questionnaire:
Name:_____
Date:_____

1) Describe how a drought effect aquifers and humans when it lasts for months. How long did your class's aquifer last?

2) What happened during the flood simulation? List at least three differences between the flood and what happened on day 1 with the Aquifer.

3) What is the GRACE satellite and why is it important? What does it measure?

4) What areas around the world are getting drier over time, what areas are getting wetter? What problems would this cause?