EES 1001 – Lab 9

**Groundwater**

Water that seeps into the ground, and is pulled down by gravity through void spaces (*see below*) in the soil and bedrock eventually percolates down to a **saturated zone**, a water-logged area wherein all the void spaces are filled with water.

The water in a saturated zone is **groundwater**.

The **water table** is the top of the saturated zone, and is the target for well drillers that want to pump out the groundwater.

*About those voids...*

**Porosity** is the volume of void space in a sediment, soil, or bedrock.

**Permeability** is the ability of water to pass through void spaces.

**Groundwater reservoir terms**

**Aquifers** are permeable bedrock layers that serve as a host to groundwater.

**Aquicludes** are impermeable bedrock layers through which water cannot pass.

**Potentiometric Surface** or **Water Pressure Surface** is the level to which groundwater will tend to rise.

A **confined aquifer** is a bedrock layer interbedded with layers that are aquicludes, referred to as the **confining beds**. This relationship means that the groundwater in the aquifer may be under pressure, so that water will flow freely out of a well drilled into it, specifically if the water table is below the potentiometric surface. Manmade wells and natural springs flowing freely from a confined aquifer are known as **artesian**.

An **unconfined aquifer** is not bounded by impermeable layers, and therefore is not confined. Groundwater must be physically pumped out of wells tapping an unconfined aquifer.

**Groundwater Hazards**

**Karst topography** is the complex of caves, lakes and sinkholes that occur in areas with limestone bedrock. Over thousands or millions of years, groundwater with organic acids dissolves away the calcium carbonate that makes up the limestone, resulting in cave formation. Sinkholes develop from the collapse of shallow caves.

**Subsidence** can occur when groundwater is removed from an aquifer more quickly than it is replaced. Without the interstitial water, the voids in the aquifer collapse under the overlying weight of material. This is expressed as uneven sinking and buckling at the ground surface.

**Pollution** from underground sources such as buried chemical waste, gas station storage tanks and garbage dumps can contaminate groundwater reservoirs and make them unusable.
<table>
<thead>
<tr>
<th>Material</th>
<th>Height (H)</th>
<th>Water Column Height (HW)</th>
<th>Horizontal Distance between Bucket and Hole (D)</th>
<th>Hydraulic Gradient (H/D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>60 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 cm</td>
<td></td>
<td>30 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td></td>
<td>45 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 cm</td>
<td></td>
<td>60 cm</td>
<td></td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>60 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 cm</td>
<td></td>
<td>30 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td></td>
<td>45 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 cm</td>
<td></td>
<td>60 cm</td>
<td></td>
</tr>
<tr>
<td>Fine Sand</td>
<td>60 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 cm</td>
<td></td>
<td>30 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td></td>
<td>45 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 cm</td>
<td></td>
<td>60 cm</td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>60 cm</td>
<td></td>
<td>15 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 cm</td>
<td></td>
<td>30 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td></td>
<td>45 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 cm</td>
<td></td>
<td>60 cm</td>
<td></td>
</tr>
</tbody>
</table>
DATA GRAPH 1
Plot HW against H/D data for each sediment tube run at each different height on the graph below (you should have four data points for each tube). Connect the data points for each tube with a line, and use a different color for each tube. Please note which color represents each sediment tube in the space provided.
Answer the following questions:

1. Does the model represent an unconfined or a confined aquifer?

2. What part of the experiment represents the recharge zone?

3. What part of the experiment represents the aquicludes (impermeable layers)?

4. What does the hole in the sediment tube represent?

5. How are the various components of your laboratory aquifer model different from actual aquifers? Describe the differences.

6. At what height (H) was the water column (HW) the highest in all three cases? Why do you think water flow was the highest at this level?

7. At what height (H) was water column (HW) the lowest in all three cases? Why do you think water flow was the lowest at this level?
8. What do you think would happen to the water column height (HW) if the height (H) between the well and water level in the bucket was 0 cm? Why?

9. At any point in the experiment did the water column flowing out of the tube hole reach as high as the water level in the bucket? What reasons might explain your observations?

10. What effect if any would changing the length on the aquifer tube have your results?

11. Which sample had the highest permeability? What do you base this on?

12. Do the sediment tubes represent well sorted or poorly sorted sediments? How would well sorted and poorly sorted sediments each affect porosity and permeability?

13. What is the relationship between the height of the water column (HW) and the hydraulic gradient (H/D)?
Using your newfound knowledge of water flow

You are the chief architect for the Roman Emperor Gaius Gluteus Maximus. He has instructed you to build a fountain with flowing water at his summer retreat, Villa Berlusconi, in the foothills of the Apennine Mountains. According to the Emperor’s orders, the water must flow at least 10 feet high in the fountain. The nearest big water source is Lake Cicero, which fills the crater of an extinct volcano.

Based on Roman engineering convention, your aqueduct must be built in a straight line from Lake Cicero to the fountain. Also, the slope of the channel must be constant, such that hills must be tunneled through and the channel must be raised above valleys on arches and piers.

Use the map, graph, and other information provided to answer the following questions.

1. What is the contour interval on the map (in feet)?

2. What is the total map distance (D) water will travel in the aqueduct from Lake Cicero to the fountain, in miles and feet?

3. What is the elevation difference (H) between the lake to the fountain?
4. What is the hydraulic gradient (H/D) along the aqueduct?

5. Determine how high water will squirt out of the fountain. How high will it go, and will it satisfy your Emperor?

6. There is a possibility that sand from Lake Cicero may accumulate in the aqueduct. Your assistant calculates that the sand will accumulate at 1 mm per month. If it takes 1 cm of sand to reduce flow in the aqueduct system such that the hydraulic gradient goes down by 0.001, then how often would the emperor’s workers have to clean the aqueduct out to keep it flowing at the 10 feet height?
Lake Cicero 975 ft.

Villa Berlusconi

North

One Mile
Based on your engineer’s calculations for loss of momentum through friction with the aqueduct channel, this graph represents the relationship of the height of the water column at the fountain versus the hydraulic gradient. Use it to predict the water column height for the aqueduct you are designing.