The Hydrogeology Challenge

www.groundwater.org

Introduction

The Hydrogeology Challenge is a learning tool that introduces students to basic groundwater modeling concepts. It uses simple calculations and assumptions to present groundwater flow in a fun and easy to understand manner.

Key Topic: groundwater flow, groundwater modeling

Grade Level: 9-adult

Duration: 45-60 minutes

Objectives:

- Understand the basics of groundwater modeling.
- Design and conduct a scientific investigation.
- Evaluate solutions to complex real-world problems.
- Use a computer simulation to model the impact of proposed solutions to a complex real-world problem.

Items Needed:

- A computer or tablet with access to internet
- Calculator (optional)

Optional Resources (found at www.groundwater.org/so.html):

- Contaminant Table
- Remediation Table

Abbreviations

G . . . . Ground Elevation

S . . . . Water Table Elevation in Static Conditions

P . . . . Water Table Elevation in Pumping Conditions

i . . . . Gradient

n . . . . Porosity

K . . . . Hydraulic Conductivity

ft . . . . Feet

△ Elev X-Y . . . The difference between the water table elevation of well X and the water table elevation of well Y

Elevation X . . The water table elevation of well X

Dist X to Y . . . The distance between well X and well Y

X-xy Dist . . . . The distance between well X and the point (xy) between well X and Y that has a water table elevation equal to the water table elevation of the middle well.

Useful Definitions

Hydrogeology - The study of interrelationships of geologic materials and processes with water, especially groundwater.

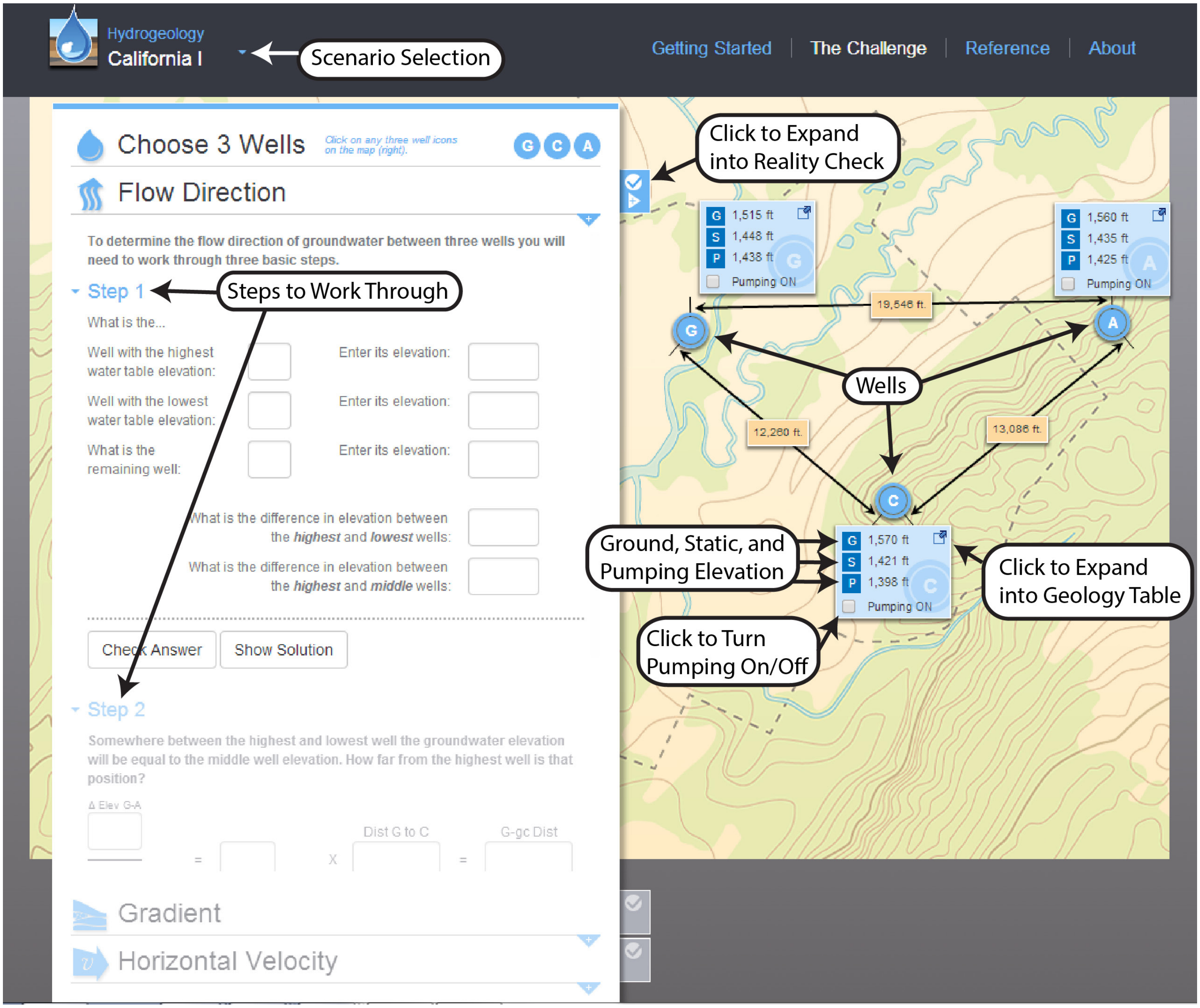
Hydraulic Conductivity - A measure of the soil's ability to transmit water through pore spaces and fractures when submitted to a hydraulic gradient.

Porosity - The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated small grain sand contains less water than coarse gravel.

Lithology - The physical characteristics of a rock or stratigraphic unit.

Water Table - The top of an unconfined aquifer; indicates the level below which soil and rock are saturated with water. The top of the saturation zone.

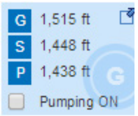
Well - A bored, drilled or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies to inject, extract or monitor water.



The Basics of Running the Hydrogeology Challenge:

1. Go to http://groundwater.beehere.net/.
2. Click the 'Start the Challenge' button.
3. Select a scenario from the blue arrow drop down box (e.g. California I).
4. Prepare your model to determine groundwater flow direction, gradient, and horizontal velocity:
   - Select three wells (depending on your browser, you may have to single- or double-click).

- You now have the option of turning well pumping on. We recommend you work through the model in static conditions first (well pumping off). If you wish to turn pumping on for a selected well, click on the white box that is labeled 'Pumping ON' in the blue well pop-up box on the map.



Note: You may move the blue pop-up box to a new location on your screen by clicking and dragging.

FLOW DIRECTION

5. Now you are ready to calculate the flow direction. To determine the flow direction of groundwater between three wells you will need to work through the three basic steps.

   For helpful information about the assumptions of the Hydrogeology Challenge, you may click the reality check button for each section.

6. Step 1: Fill in the blank boxes with the necessary information. When filling in information about water table elevation, make sure to use the 'Water table elevation in Static conditions (S)' for wells that are not pumping and use the 'Water table elevation in Pumping conditions (P)' for wells that are pumping. You must fill in all of the boxes for Step 1 before you may move on to Step 2.
7. Step 2: Fill in the blank boxes with the necessary information. Make sure to round your answers to the stated amount of decimal places. The distance between wells is shown on the map. You may use a calculator to help you answer the math questions. Upon completion of step 2, you will notice a grey line appears on your map. This is your water table contour line.
8. Step 3: Select the direction of groundwater flow. Groundwater flows from regions of higher elevation to regions of lower elevation.
9. Once you have completed all three steps you may move on to Gradient. If you wish to check your answers, you may select the 'Check Answer' button.This will highlight your answers in green if they are correct or red if they are incorrect. To view the correct answers, select the 'Show Solution' button.

GRADIENT

10. Determining the gradient is an important part of calculating groundwater flow because it is necessary for determining the velocity of the groundwater flow.
11. Step 1: Click on 'Reveal Distance Y'. Distance Y is the flow distance perpendicular to the water table contour (grey line) that you determined in Flow Direction. Distance Y will appear on your map.
12. Step 2: Complete the formula to determine the gradient (i). Once again, make sure to round your answers to the stated amount of decimal places.
13. A visual of the gradient will appear as a yellow arrow under the Step 2 equation. You are now ready to proceed to the final step: Horizontal Velocity.

HORIZONTAL VELOCITY

14. Horizontal Velocity is calculated using Darcy's Law. Darcy's Law requires the hydraulic conductivity (K) and porosity (n) of the soil through which the groundwater is moving. To find these values, open the Geology Table of the well with the highest water table elevation (this is the well the groundwater will be flowing from). The Geology Table shows the lithology (soil type) where the well is located. The depth is listed as feet below the surface. **To select your K and n values, choose the layer of soil with the highest conductivity (K) in the saturated zone (area below the water table).**

15. Step 1: Determine your hydraulic conductivity (K) and porosity (n). Fill in the blank boxes with the necessary information. You may back track to Gradient if you forgot your gradient value. Remember, porosity is entered in as a decimal, so a porosity of 45% would be entered as 0.45.

16. Step 2: Complete the equation (Darcy's Law) to calculate Horizontal velocity.

FINISH

17. Congratulations! You have successfully calculated the speed and direction of groundwater flow. You may now click the 'All Done' button.

18. A prompt will appear allowing you two choices: 1) "Continue with Previous Selection", and 2) "Begin a New Scenario". Select "Continue with Previous Selection" if you wish to return to the well selection you have just completed, and select "Begin a New Scenario" to clear the scenario and allow you to either select three new wells with the same scenario or select a new scenario.

19. If you "Begin a New Scenario", don't forget to try the Hydrogeology Challenge with well pumping ON!

FOR MORE FUN

The Hydrogeology Challenge can be utilized in the classroom in many fun and exciting ways. Once students have the basics down on how to calculate the flow direction, gradient, and horizontal velocity of groundwater using the Hydrogeology Challenge, try out some of these fun activities:

1. Experiment with well pumping. How does turning pumping on effect the groundwater flow for a certain scenario? What consequences could this have in real life? What assumptions does the Hydrogeology Challenge make for well pumping? How can these assumptions lead to model output (answers) that are different from what would happen in reality?
2. Incorporate contamination into the scenario. Select a contaminant from the Contaminant Table located on The Groundwater Foundation's website www.groundwater.org/kids/getinvolved/so/hydro.html. Assume this contaminant is located at one of the wells in the scenario you have selected. Using the Hydrogeology Challenge, determine which wells are at risk of being contaminated by the pollutant. How long will it take for the pollutant to reach the at-risk wells? Look up remediation techniques that could be applied to this situation, and create a presentation on these techniques. What are the costs, both monetary and environmental, of using remediation techniques to clean up contaminated groundwater? Which techniques are most effective? Is there a real-life example where this technique has been applied to clean up this pollutant? How long did it take?
3. Research groundwater flow computer models that are currently being used by professional hydrogeologists today (e.g. MODFLOW). What assumptions do these models make? How are they different from the Hydrogeology Challenge? How are they similar?

Alignment to Next Generation Science Standards

HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts

HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the position