The Hydrogeology Challenge: Water for the World

TEACHER’S GUIDE

Why is learning about groundwater important?

- 95% of the water used in the United States comes from groundwater.
- About half of the people in the United States get their drinking water from groundwater.

In the future, the water industry will need leaders that can understand, interpret and manipulate groundwater models to make informed decisions. Geologists, agricultural scientists, petroleum engineers, civil engineers, and environmental engineers play an important role in deciding how to use and protect groundwater.

The Hydrogeology Challenge introduces students to groundwater modeling and the role it plays in groundwater management. It challenges students to use an interactive computer model to think critically about groundwater resources. The Hydrogeology Challenge has been successfully utilized in many educational settings including as a Division C (high school level) Science Olympiad event.

INTRODUCTION

The Hydrogeology Challenge introduces groundwater characteristics in a fun and easy to understand way. It leads students step-by-step through a series of simple calculations that reveal information about how groundwater moves.

The Hydrogeology Challenge can be used in a variety of ways in the classroom:

- a teacher-led activity
- an independent student activity
- a team activity

This instruction guide demonstrates key principles of the computer program so you can comfortably use the Hydrogeology Challenge in your classroom.

Additional features to enhance student learning are available (information on page 6).

KEY TOPICS: Aquifer, Contamination/pollution prevention, Earth science/geology, Groundwater, Water use

GRADE LEVEL: 9 - 12

DURATION: 30 - 45 minutes

OBJECTIVES: Understand basic groundwater modeling | Determine groundwater characteristics through basic calculations | Understand assumptions of the computer model.

Hydrogeology: Water for the World is a program of The Groundwater Foundation. Find us online at www.groundwater.org. Questions? Contact us at 1-800-858-4844 or at hydro@groundwater.org.
What will students learn?

Students will calculate three basic groundwater characteristics in the Hydrogeology Challenge computer model:

1. **Flow Direction** - Groundwater can move in any direction—vertically, horizontally, north, south, east or west. Like rivers and streams, groundwater moves from areas with higher water table elevations to areas with lower water table elevations.

2. **Gradient** - The groundwater gradient can be thought of as the slope of the water table.

3. **Horizontal Velocity** - The horizontal velocity is the speed in which groundwater moves through an aquifer, in the Hydrogeology Challenge it is given in feet per day.

What do these characteristics mean?

Students will use the Flow Direction, Gradient and Horizontal Velocity values to determine how water (and a contaminant) can move through an aquifer using calculations based on Darcy’s Law. Darcy’s Law describes how a liquid flows through a porous medium. Velocity is equal to the hydraulic conductivity times the gradient divided by porosity.

\[ V = \frac{Kx}{n} \]

The information provided by Darcy’s Law helps managers make informed decisions that are in the best interest of our groundwater resources and people.
Getting Started: The Hydrogeology Challenge

SUPPLIES YOU’LL NEED
- Computer with internet access*
- Calculator
- Writing utensil
- Paper

*If you do not have access to a reliable internet connection, a paper version, which does not require internet access, is available. Contact The Groundwater Foundation at hydro@groundwater.org.

ABBREVIATIONS & DEFINITIONS

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

Elevation X - The water table elevation of well X
Elev X-Y - The difference between the water table elevation of well X and the water table elevation of well Y
Dist X to Y - The distance between well X and well Y

Go to http://groundwater.beehere.net using any up-to-date browser to access the model.

GET STARTED! Go to http://groundwater.beehere.net using any up-to-date browser to access the model.

HELPFUL FEATURES:
> Select a scenario from the drop-down menu. Each scenario has unique well placement, topography and geology.

> Follow the directions on the left-hand side. To choose three wells, single or double click (depending on your browser) the wells on the map.

Be sure to use S-value (water table elevation in static conditions) for wells not pumping, or use P-value (water table under pumping conditions) for wells that are pumping.

Notice that some answers require rounding.
As you work through the steps, lines will form on the map. The first line to appear is yellow and represents the distance from the well with the highest water table elevation to the well with the lowest water table elevation.

**Step 2:** A grey line will appear when you complete the formula. This line is from the middle well to a point (ce) on the yellow line where the water table is equal to that of the middle well and represents a water table contour line.

**Step 3:** The flow direction (represented by a blue dashed line) will always be perpendicular to the contour line. Click and drag the blue dot around the compass until the blue dashed line on the map is perpendicular to the gray contour line, this will provide the flow direction in degrees.

>As you complete each section, the next section becomes bold.

>Note: You may move the blue pop-up boxes that contain information about each well by clicking and dragging.

>Click here to turn pumping ON. We recommend you first work through the model in static conditions (pumping off). Wells that are pumping will lower the water table elevation in the vicinity of the well.

>For helpful information about the assumptions of the Hydrogeology Challenge versus real life situations, click the reality check button. Each of the three sections has its own reality check with information. In order to make a working model for students to use, complex geologic factors needed to be simplified.

>As you complete each section, the next section becomes bold.
Step 1: Begin by plugging in the value you found in the gradient section. If you did not write down the gradient (i) you can go back by clicking the “Gradient” tab.

Next, open the geology table for the well with the highest water table elevation by clicking in the top right corner.

The geology table displays the aquifer material, its hydraulic conductivity, and porosity.

The Hydrogeology Challenge assumes that groundwater is mainly flowing through the saturated layer with the highest conductivity, K. Use the geological layer within the saturated zone that has the highest K value.

Don’t forget to look at the reality check to find out more about the gradient of groundwater!
HORIZONTAL VELOCITY (CONTINUED)

To determine which geology layers are in the saturated zone, you must first determine the depth of the water table. Find the depth of the water table by subtracting the water table elevation (S in static conditions) from the ground elevation (G).

\[ G - S = \text{water table depth in feet} \]

In this example: \( 2,654 \text{ feet} - 2,591 \text{ feet} = 63 \text{ feet} \)

The water table is found 63 feet below the surface in the “Sandstone” layer. The “Gravel” layer, located below the “Sandstone” layer, is also in the saturated zone and has a higher conductivity, use the K-value (conductivity) and n-value (porosity) for the “Gravel” layer in Steps 1 and 2.

Complete the equation (Darcy’s Law) in Step 2 to find the Horizontal Velocity. In this scenario, the horizontal velocity is 7.61 feet per day.

\[ V = \frac{K \times i}{n} \]

CONGRATULATIONS! You have successfully calculated the speed and direction of the scenario’s groundwater flow. Using this information, you can determine in which direction and how fast a contaminant will move through an aquifer.

Click ‘All Done’ to either continue the same scenario or begin a new scenario.

TEST YOUR STUDENTS’ ABILITY TO USE THE MODEL:

The Hydrogeology Challenge is also available in test mode. To obtain a test mode scenario you need to contact The Groundwater Foundation at hydro@groundwater.org to obtain test URLs and instructions. The Hydrogeology Challenge in test mode:

- Does not have show solution/check answer options
- Does not have the reality checks
- Enables students to submit answers
- Enables educators to receive graded results

CHALLENGE YOUR STUDENTS TO APPLY THE KNOWLEDGE GAINED

Now that the Horizontal Velocity has been determined, challenge your students to address real situations and derive solutions to contamination threats. Provide them with a realistic narrative of a community who’s drinking water is in danger. Students are given the facts of the case and must discover the most time and cost efficient way of saving the water supply. To obtain the Applied Knowledge challenges contact The Groundwater Foundation at hydro@groundwater.org. Include your name, the name of the school and grade level.
STUDENT WORKSHEETS:

Students can work through the following worksheet and the Hydrogeology Challenge at the same time to learn how groundwater moves through the earth and to determine groundwater flow characteristics. Depending on the length of time you have to dedicate to the subject of groundwater, other resources are available to apply the information calculated in the computer model to realistic situations including: pumping conditions, groundwater contamination and remediation of contamination.

ADDITIONAL RESOURCES:

- Visit www.groundwater.org/kids/getinvolved/so/hydro.html for:
  - A 10-minute video walkthrough that will take you step-by-step through running the Hydrogeology Challenge.
  - A Contaminant Table
  - A Remediation Table
- The U.S. Environmental Protection Agency’s Citizen Guide series, a set of 22 fact sheets that summarize cleanup methods - https://clu-in.org/products/citguide/
Name:

Work through the Hydrogeology Challenge and answer the questions below. Be sure to read through the “reality checks.”

Groundwater Basics and Flow Direction

1. Match the terms with their definitions:

A. Unsaturated Zone
B. Groundwater
C. Saturated Zone
D. Water Table
E. Surface Water

___ The portion below the earth’s surface that is saturated with water.

___ The top of an unconfined aquifer; indicates the level below which the soil and rock are saturated with water.

___ The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. Plant roots can capture the moisture passing through this zone, but it cannot provide water for wells.

___ Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater and runoff.

___ Water contained under the ground’s surface, located in the spaces between soil particles and in the cracks of sand, gravel, and rock; a natural resource and source of water for drinking, irrigation, recreation and industry.

2. The upper surface of the _____ is called the water table.

A. Discharge area
B. Saturated zone
C. Confining zone
D. Unsaturated zone

3. True or False: Porosity is the ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment.

4. True or False: Saturated small grain sand holds less water than coarse gravel.
5. In the Hydrogeology model, “static conditions” refer to a situation where…
   A. Wells are not pumping
   B. Wells are pumping

6. How can groundwater move?
   A. Vertically
   B. Horizontally
   C. North
   D. South
   E. East
   F. West
   G. All of the above

7. True or False: Groundwater moves from areas with higher water table elevation to areas with lower water table elevation.

8. In order to determine the flow direction of groundwater, the water table elevation must be known at a minimum of ____ locations:
   A. 1
   B. 2
   C. 3
   D. 4

9. Groundwater in the vicinity of a pumping well will…
   A. Rise
   B. Fall
   C. Stay the same
10. How does pumping a well affect the flow of groundwater in the Hydrogeology Challenge? In real life? Explain or draw a picture for both scenarios.

**Gradient**

11. In the Hydrogeology Challenge, a pumping well creates a cone of depression, a zone around a well that is normally saturated, but becomes unsaturated as the well is pumped. The Hydrogeology Challenge assumes a constant gradient between the water table elevation of the pumping well and the surrounding area (illustrated to the right). In reality, how does pumping affect the area around a well? Explain or draw a picture.

**Horizontal Velocity**

12. Darcy’s Law is used to determine \[ \frac{K}{n} \times i \].

13. Define the variables of Darcy’s Law:

\[ V = \frac{K \times i}{n} \]
14. Hydraulic conductivity is the measure of the soil’s ability to transmit water. State whether the soil types will have high or low hydraulic conductivity.

Coarse-grained soils:
Clay soils:

15. True or False: Groundwater can move through all layers of saturated rock and soil, even geologic layers with very low hydraulic conductivities.
Name:

Work through the Hydrogeology Challenge and answer the questions below. Be sure to read through the “reality checks.”

Groundwater Basics and Flow Direction

1. Match the terms with their definitions:

A. Unsaturated Zone
B. Groundwater
C. Saturated Zone
D. Water Table
E. Surface Water

   C. The portion below the earth’s surface that is saturated with water.
   D. The top of an unconfined aquifer; indicates the level below which the soil and rock are saturated with water.
   A. The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. Plant roots can capture the moisture passing through this zone, but it cannot provide water for wells.
   E. Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater and runoff.
   B. Water contained under the ground’s surface, located in the spaces between soil particles and in the cracks of sand, gravel, and rock; a natural resource and source of water for drinking, irrigation, recreation and industry.

2. The upper surface of the _____ is called the water table.

   A. Discharge area
   B. Saturated zone
   C. Confining zone
   D. Unsaturated zone

3. True or False: Porosity is the ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment.

4. True or False: Saturated small grain sand holds less water than coarse gravel.
5. In the Hydrogeology model, “static conditions” refer to a situation where…
   A. Wells are not pumping
   B. Wells are pumping

6. How can groundwater move?
   A. Vertically
   B. Horizontally
   C. North
   D. South
   E. East
   F. West
   G. All of the above

7. True or False: Groundwater moves from areas with higher water table elevation to areas with lower water table elevation.

8. In order to determine the flow direction of groundwater, the water table elevation must be known at a minimum of ____ locations:
   A. 1
   B. 2
   C. 3
   D. 4

9. Groundwater in the vicinity of a pumping well will...
   A. Rise
   B. Fall
   C. Stay the same
10. How does pumping a well affect the flow of groundwater in the Hydrogeology Challenge? In real life? Explain or draw a picture for both scenarios.

![The Hydrogeology Challenge](image1)
![Real life conditions](image2)

**Gradient**

11. In the Hydrogeology Challenge, a pumping well creates a cone of depression, a zone around a well that is normally saturated, but becomes unsaturated as the well is pumped. The Hydrogeology Challenge assumes a constant gradient between the water table elevation of the pumping well and the surrounding area (illustrated to the right). In reality, how does pumping affect the area around a well? Explain or draw a picture.

![Gradient](image3)

**Horizontal Velocity**

12. Darcy’s Law is used to determine the flow of groundwater through an aquifer.

13. Define the variables of Darcy’s Law:

\[ V = \frac{K x i}{n} \]

- \( V \) = the seepage velocity of groundwater
- \( K \) = hydraulic conductivity
- \( i \) = gradient of the water table
- \( n \) = porosity
14. Hydraulic conductivity is the measure of the soil’s ability to transmit water. State whether the soil types will have high or low hydraulic conductivity.

Coarse-grained soils: High
Clay soils: Low

15. True or False: Groundwater can move through all layers of saturated rock and soil, even geologic layers with very low hydraulic conductivities.