MiSP PERMEABILITY AND POROSITY
Teacher Guide

Introduction

This MiSP unit focuses on the topic of groundwater in high school Earth science courses. Although most of Earth's surface is covered by water, the supply of fresh, uncontaminated water is becoming an endangered resource in many Earth locations. Because of the growing problems with surface water, scientists are expanding their studies about the fate of water that infiltrates Earth.

Water that flows on the land surface in streams, or lies in lakes and marshes, is called *surface water*. The water that lies beneath the land surface, occupying the pores of the soil or bedrock, is termed *subsurface water* or *groundwater*. The nature of the ground material (rock, sand, silt, clay) determines how much water can be held and how easily it can be transported.

Porosity is a measure of how much space there is between the particles of Earth materials, how the space is affected by these particles' shapes, how tightly the material is packed, and to what extent the particles are sorted.

Some materials are permeable (water can pass through the spaces/pores between particles). Other materials are impermeable.

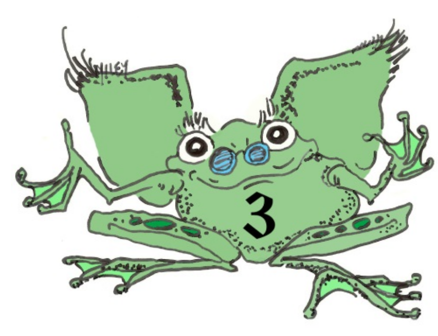
Standards

Physical Setting/Earth Science Core Curriculum — Major Understandings:
Standard 4 Physical Setting 1.2g

Lesson Objectives: After completing this unit, students will be able to:

- Define *permeability*, *porosity*, and *water retention* / *water retained*, and explain factors that affect the rate at which water passes through particles such as sand

- Follow experimental procedures to determine permeability, water retained, and porosity
- Use data and graphs to relate particle size and permeability, water retention, and porosity
- Extrapolate and interpolate data
- Determine and use the unit rate of change to analyze data (L2)
- Determine and apply formulas for lines, where appropriate, to relate particle size to groundwater measurements (L3).



Day 1 — Introduction to Groundwater Concepts

Introduce or review these terms: *surface water*, *groundwater*, *infiltration*, *porosity*, *permeable*, *impermeable*, *pore space* (optional terms are *aquifer*, *aquitard*, *water table*, *percolation*, *recharge*, *zone of saturation*, *zone of aeration*, and *capillarity*).

For useful visuals, see the following Internet resources:

http://www.scwa.com/education/watercycle.cfm
http://belmont.sd62.bc.ca/teacher/geology12/photos/erosion-water/permeability.gif

http://www.euwfd.com/assets/images/Groundwater-pollution02.jpg

http://belmont.sd62.bc.ca/teacher/geology12/photos/erosion-water/porosity-low-high.jpg

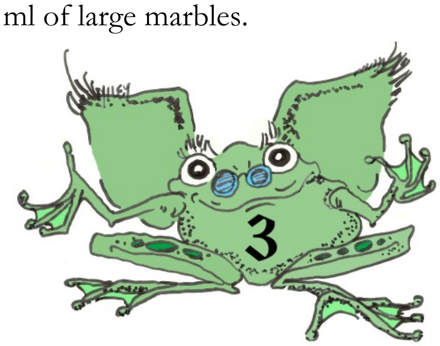
Demonstrations to introduce the concepts of porosity, water retention, and permeability follow.
Porosity and Water Retention:

1. Measure 50 ml of sand and 50 ml of water in separate graduated cylinders.
2. Ask students to predict the volume of the mixture of the two when combined.
3. Pour the water into the sand and measure the volume. Discuss the reason for the volume being less than 100 ml. Note the term *porosity*.
4. Ask students to predict what will happen when the water is poured back into its original cylinder. Will 50 ml of water be recovered?
5. Pour the water back into the original cylinder and measure the volume. Discuss. Introduce the term *water retention.*

Permeability:

1. Measure 300 ml of sandy soil and silt into separate clear containers.
2. Show the students the containers of sand or silt. Ask them to predict whether water will seep into the ground faster on silt or on sandy soil.
3. Pour 100 ml of water on top of the silt, and measure the amount of time it takes for the water to disappear from the surface. Pour 100 ml of water on top of the sandy soil and measure the amount of time it takes for the water to disappear from the surface. Discuss. Note the term *permeability*.
4. Ask which type will hold more water before forming a "puddle" on top.
5. Measure 500 ml of water in a graduated cylinder. Add water to the containers of silt and sandy soil until there is 1.0 cm of water resting above the surface.
6. Determine the amount of water that is left, and determine how much water was needed to form a 1.0 cm puddle on the top of each type of soil. Do not forget to include the 100 ml you added earlier. Discuss.

After discussing the demonstrations above, students should be coming to the understanding that the difference in how quickly water infiltrates different soils and the differences in ability to retain water are dependent on the amount of space between the individual particles of matter. To reinforce the concept, use a container of sand and water from the previous activity and 300 ml of large marbles.



Pour the same amount of water into the marbles as you added to the sand. The water will not cover the marbles.

Students should know that porosity is a measure of the empty space that is potentially available for water storage in a geologic material. It is the percentage of empty space in a given volume of material. Permeability is the *rate* at which moisture passes through a material. The rate in this case is the same as the more familiar concept of speed and is equal to Δ distance/ Δ time.

Students will be expected to know that some materials are impermeable. Pouring a small amount of water on the desktop will remind students that water doesn't seep into the desk. The desk is impermeable. Water that does not infiltrate is called *runoff*.

Question of the Day:

Clay has high porosity. Clay is also impermeable. If there is a high percentage of space in clay, why can't water pass through it?

Days 2, 3, and 4 — Water Movement Through the Ground

This activity is based on the procedures in Osmun, Vorwald, and Wegner, *Explorations in Earth Science*, UPCO, 2001. There are many similar versions of this lab protocol.
For these alternative procedures, see:

http://www.esi.utexas.edu/outreach/gk12/docs/lessons/investigating.pdf

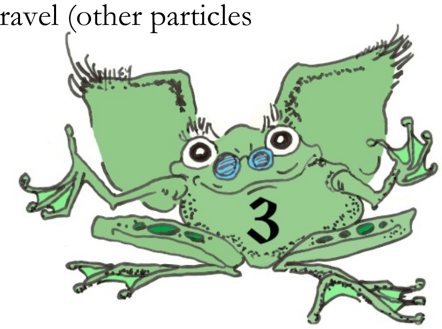
http://www.saddleback.edu/faculty/jrepka/notes/GEOporpermLAB.pdf

http://curriculum.new-albany.k12.oh.us/lsomerlot/documents/Porosity-PermeabilityLab.pdf

Unlike other MiSP units that have two activities spread out over days 2, 3, and 4, this unit has one big activity with three sets of data (permeability, porosity, and water retention) to analyze. The levels 2 and 3 analyses for water retention are "reduced" MiSP analyses. However, since most units with two activities require two sets of data and graphs, teachers may choose to eliminate the water retention graph and discussion (L1, 2, or 3). Teachers will decide how much work will be done in class and how much to assign for homework.

Teachers will have to decide between using beads and using sorted Earth materials (like fine, medium, and coarse sand). The worksheet is set up for beads.

Before the lab work begins, introduce the idea of sorted versus unsorted (mixed) particles. To demonstrate the difference, hold up one container of sand, one container of gravel (other particles



such as rice and beans, or beans of different sizes, can be substituted, but it is more relevant to use the "Earth" materials), and one container of sand mixed with gravel. Students should predict which container will have the lowest permeability and which will have the highest permeability, and explain why.

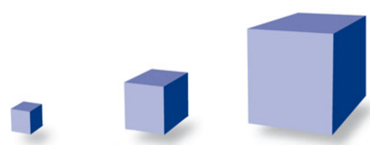
The beads are well-sorted particles. Alternative materials must also be well sorted.

The data, graphs, and discussion at all three levels are challenging and will require teacher monitoring and guidance.

Students often have difficulty with the fact that equal volumes of well-sorted materials have the same porosity regardless of particle size. You can easily demonstrate that the total pore space is equal by holding up two clear containers holding equal volumes of sorted particles of different particle size (large and small marbles work very well). Pour equal amounts of water into each container and ask students to observe the water level in each. Mark this level with a dry erase marker. Ask students to explain why the materials in the two containers have equal porosities.

Students seem to know intuitively that the water is retained on the particles because it adheres to their surfaces. The recognition that more water is retained on the small particles opens the opportunity to discuss surface-volume relationships:

(A) Cubes



	1-mm cube	2-mm cube	4-mm cube
Surface area	6 sides × 1^2 = 6 mm^2	6 sides × 2^2 = 24 mm^2	6 sides × 4^2 = 96 mm^2
Volume	1^3 = 1 mm^3	2^3 = 8 mm^3	4^3 = 64 mm^3
Surface area-to-volume ratio	6:1	3:1	1.5:1

LIFE 8e, Figure 4.2 (Part 1)

(B) Spheres

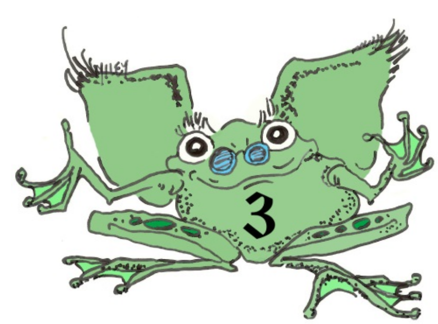
Diameter	1 µm	2 µm	3 µm
Surface area $4 \pi r^2$	3.14 μm^2	12.56 μm^2	28.26 μm^2
Volume $4/3 \pi r^3$	0.52 μm^3	4.19 μm^3	14.18 μm^3
Surface area-to-volume ratio	6:1	3:1	2:1

LIFE 8e, Figure 4.2 (Part 2)

Question of the Day:

What kind of material would you put in a playground to ensure that rainwater infiltrates the ground and does not make puddles? What would be the nature of the particles in garden soil if you wanted it to hold water in the pores between particles to enable you to reduce the watering of the garden?

Day 5 — Assessment



Administer the assessment: *MiSP Permeability and Porosity Assessment*.