Using the scientific method to guide this outdoor investigation, students test the permeability of different school-ground areas, record and organize the results with maps and tables, and make recommendations for sustainable stormwater practices. The following are included:

- Teachers Instructions: Pages 1-3
- Student Directions for Permeability Field Test: Page 4
- Extensions for math, soil exploration, stormwater solution preplanning: Page 5
- Student Observation Sheet: Page 6
- Sample Group Table: Pages 7-8

Concepts: Permeability, infiltration; surface water runoff on different surfaces; sustainable practices that reduce storm water runoff on the school grounds; reliability in scientific research.

Skills: Using Scientific Method; methods for recording and organizing data; communicating results; recommending sustainable stormwater practices; basic math and averaging with extensions for volume and unit conversion.

Grades: 5-10

Time: 60 to 90 minutes, depending upon number of test sites, extensions, and involvement of students in map preparation.

MD STEM Standards of Practices: 1, 2, 3.

Prior Knowledge

This activity works well after the Score Four Watersheds, Land Use, and Sustainable Practices (PPT) presentation and FieldScope (or other map) activity; the Watershed Connections model activities; or other lessons that provide the necessary background for students to form a hypothesis and discuss the issues and possible solutions.

Prepare students to understand and/or participate in the design of this field study by reinforcing concepts of hypothesis, accuracy, reliability, and validity.

Supplies for Each Team

- 6-inch PVC pipe 3-in diameter (can be cut with a hacksaw). Draw a line .25 inches (.6 cm) from the bottom on this cylinder with a Sharpie. (Option: coffee cans with both ends removed. Make sure the cans are the same size and that sharp ends are covered with duct tape.)
- 1000 ml-measuring cup
- Stop watch
- Small map of school grounds
- Clear ruler with metric marks
- Red, green, and yellow markers and pencil
- Directions for Permeability Field Test
- Field Observation Sheet
- Container of water for multiple sites (could be a 2-liter soda bottle)

Supplies For Whole Class

- Large map of school yard on large paper
- Large pad of paper, easel, markers, pencil for class data table
- Extra water

Preparation

Make Large & Small Campus Maps: Make a large map of the school grounds, depicting the school and campus areas that have different uses and/or land cover — for example, gardens, woods, parking lots, playgrounds, paths, sidewalks, or athletic fields. You can print out a computer satellite map of the grounds, or have students create a line drawing. The map is used for preliminary discussion and the class data. (A large paper map provides the benefit of a physical communication piece to display about your project, but some teachers prefer displaying the large maps and data on PowerPoint.) *Each team also needs a small version of this map.*

Outdoor Discussion with Map: Take your students outside and, using the map(s), ask them which areas on the school grounds might have differing amounts of *permeability*. Explain that they will do a field test to assess the permeability of areas on the school grounds that have different uses or land cover. Discuss factors that could affect the ability of water to *infiltrate* into the soil.

Hypothesis: Ask your students to make group hypotheses about which *area has the greatest permeability and which has the least*. The hypotheses should be backed by information from lessons or observations. For instance, gardens could be the most permeable because roots create air spaces in the soil or the ground is looser. The playground could have less infiltration if it has been compacted by students (fewer air spaces for water to infiltrate). A paved parking lot would not allow water to infiltrate into the ground.

Methods

Setting Up the Field-Test Process: For higher grade levels, the students should give input to this part of the experimental design, considering the concepts of accuracy, reliability, repeatability, and validity, as they do so. Our suggestions follow.

1. Divide the class into four to six teams and call them Teams A, B, C, etc.
2. Decide how many teams will test each area — keeping in mind that the *data from each area will be averaged*; the more tests in each area increases the *validity* of the results.
3. Have the class discuss which areas to test. The areas should be distinctly different uses or land covers. (Alternately, teachers can select the areas and assign each team several areas to test.)
4. Explain that each team will *use the same methods* to test a *different spot within that area to maintain reliability and validity*.

   Time-saving options: Focus your investigation on one side of the school; have different classes test different areas, and combine the results from both classes; or each team could test 3-4 different areas, with each area being tested by a minimum of 3 teams.

   Added Challenges: If age appropriate, introduce the concept of *random sampling within the defined areas* by having each team pick a number from a hat. Then one team member twirls around in the center of the area (with eyes closed) and walks that # of steps to the spot to be tested.)

Permeability Field Test (see Student Directions, page 4): These directions can be copied for the students.

- Demonstrate the test and go over the *Team Field Observation Table* (page 6).
- Provide each team with the materials listed on page 1. Assign "jobs" for the team members. For example, holding the cylinder, pouring the water, working the timer, recording the data, and marking the map. Have each team practice the procedure.

  - Ask the students why it is important for all of the teams to use the same procedure. Answer: *Reliability* — if one team were to use a different amount of water, the results would not be consistent with the other teams' data. Repeatedly using the same methods helps ensure consistency of the results. This makes it possible to average the results and have a reliable conclusion, or to recognize an anomaly.
  - Ask them why they have assigned jobs and need to practice the procedure. It improves *accuracy*, because the students are less likely to make a mistake in the procedure. It improves *reliability* of the results, because the students are more likely to do each test the same and the same as the other students.

Recording the Results

Each team records their data and observations on the Team Map and Team Field Observation Table. When the field tests are done, the class gathers to record the results on the group map and a group table.

Group Map: Each team marks their sites on the large map according to the following:

- If all the water seeped into the ground within **3 minutes**, put a **GREEN dot** on the test site. Draw an arrow showing the direction of flow.
- If **less than 2 cm** infiltrated into the ground, mark the test site with a **RED arrow**, showing the direction of water flow.
- If **some water remained in the cylinder, but greater than 2 cm infiltrated** into the ground, put a **YELLOW dot** on the test site. Draw an arrow showing the direction of flow.
- Extrapolate the results: If all the test sites in a designated area have the same color of dots, mark the entire area with that color (or stripes of that color).
- Make a map key. Have the students define what the colors and symbols represent – *permeable, semi-permeable, or impermeable.*

Group Table: Have the group make a table to record their results, or use the one provided on page A. The students will *average* their results.

Conclusions and Recommendations

Sample class discussion questions

- Which areas are the most permeable and impermeable? Was the group hypothesis correct? Why or why not?
- What direction would runoff flow in different areas of the school yard?
- Which areas would have the most stormwater runoff? (What other information might be needed to quantify this question? Answer: size of the area or the roof; slope.)
- Which areas might have puddles?
- Why does the water infiltrate at different speeds in different areas? Possible answers:
    - The area is compacted by people walking or playing on it.
    - Heavy lawn mowers frequently run over it.
    - There is clay underneath the top soil or near the surface.
    - There is mulch and dried leaves on top of the ground.
    - There are plants with roots in the soil.
    - There is more sand or loam or organic material in the soil.
- How does these findings relate to stream water quality in their watershed?

- PRACTICAL APPLICATION: Where could sustainable stormwater practices, such as gardens or rain barrels, be installed to reduce stormwater runoff? *(See the rain garden resource booklets on your CD for more information on this.)*
    - Have students suggest best management practice and discuss the pros and cons of each type.
    - Students can discuss what else they would need to know before deciding what practices would be most effective.

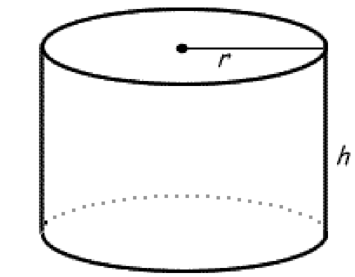
Procedure

As you complete each test, mark the *site on your map, and* record your observations on the Team Field Observation Sheet. Label each test site according to your team's letter and the number of the test. (If you are team A, your first site will be labeled A1, your second site, A2, and so on.)

Each team member should do his or her assigned task throughout the investigation (Reader, Recorder(s), Holder, Timer, Pourer). Read and *practice* these instructions before you start.

1. Fill your cup or bottle with 650 ml of water.
2. Push the cylinder into the ground to the black line on the cylinder. (For areas where the pipe *cannot* be put in the ground, go to Step 3.) Do the following steps:
   - One person applies constant pressure to the top of the container to prevent water from leaking out around the bottom.
   - The Timer starts the stopwatch at the same time the Pourer begins to pour water into the cylinder.
   - *If the water infiltrates before 3 minutes*, the Timer stops the watch at that point. The Data Recorder writes the length of time on the Team Field Observation Sheet.
   - Stop the watch at 3 minutes. If water remains in the cylinder, measure from the rim of the cylinder to the water level (in centimeters). The Data Recorder notes this on the Observation Sheet.
3. If the cylinder cannot be put into the ground, you will pour the water on the surface and record what happens on your table and map.
   - Does it pool?
   - Does it flow in a certain direction? Make a red arrow on your map that shows which direction the water flows.

Extensions



Volume $V = \pi r^2 h$

Finding the volume of a cylinder:

The volume is found by multiplying the *area of one end of the cylinder (base) by its height.*

Since the end (base) of a cylinder is a circle, the area of that circle is given by the formula: area = πr^2

$volume = \pi r^2 h$	where: π is Pi, approximately 3.142 r is the radius of the circular end of the cylinder h height of the cylinder

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Extension 1 – Volume:

What volume of water is needed to fill the cylinder?

Have the students use the metric system to measure the cylinder's height (from the marked line) and diameter. They will determine the radius by dividing the diameter in half.

Our cylinder: Diameter = 7.7 cm. Height = 14.6

$volume = \pi r^2 h$ = 3.14 x (7.7 cm ÷2)^2 x 14.6 = 679.8 ml

Students also can determine the volume of water that percolated, using same method. Conversely, they can determine the volume of water left in the container, which represents runoff.

Extension 2 – Rate of Infiltration and Conversions: Although most sciences use the metric system, the science of hydrology often uses English units. The rate of infiltration is measured in either mm/hour or inches/hour. Have them convert their measurements (cm/minutes) to mm/hour or inches/hour. Naturally, if the test was done for 24 hours, as it is by soil conservation scientists, this rate could differ, which raises another point of discussion about the accuracy of the results.

Other Extensions

- Have students hypothesize what variables might be included in a formula for the amount of runoff that runs off roofs and then research the formula on the internet. The students could then calculate how much runoff would be expected on the school grounds from the school roof. (Many reliable internet sites on rain barrels and rain gardens include formulas. Good sources include county environmental departments. Also see the rain garden booklets provided on ICPRB's Score Four Resources.)
- Have students consider variables on the ground and in the soil that would affect the rate of infiltration (e.g., types of vegetation, recent rain activity, soil types.) The National Soil Conservation Service website provides lessons and videos on this subject. Ensuing Score Four lessons also focus on this topic.

TEAM FIELD OBSERVATION SHEET

Weather: Did it rain yesterday? _____________

TEST SITE NUMBER (For example, A1, A2, A3…	**TEST SITE DESCRIPTION** (Examples: garden, foot path, playground, parking lot)	**TIME FOR WATER TO INFILTRATE (sec.)** (If the water would not infiltrate, write impermeable.)	**Distance from rim to the water level (cm)** (The amount that infiltrated.)	**OBSERVATIONS** • Note things that could have influenced your results, for instance: Was the ground wet? Did water seep out your cylinder?

EXAMPLE CLASS TABLE

Directions:

Time to infiltrate: If the water did not infiltrate within 180 seconds, write **>180 sec**. If it did not infiltrate at all, write Impermeable.

Averaging: When the water does not infiltrate within 180 seconds, it will take creative thinking to "average" the Time-to-Infiltrate results. Your class can decide the appropriate value to use, or whether to just to consider the average amount of water that infiltrated for that site.

Distance from rim: If the water did not infiltrate into the ground at all, write zero.

	Test Site 1		**Test Site 2**		**Test Site 3**		**Test Site 4**	
	Time to Infiltrate (seconds)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (seconds)	Distance from Rim to Water Level (cm)	Time to Infiltrate (seconds)	Distance from Rim to Water Level (cm)
Team A								
Team B								
Team C								
Team D								
Team E								
Average								
Is it Permeable or Semi-permeable Or Impermeable?								

	Test Site 5		Test Site 6		Test Site 7		Test Site 8	
	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)*	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)
Team A								
Team B								
Team C								
Team D								
Team E								
Average Time to Infiltrate								
Is it Permeable or Semi-permeable or Impermeable?								