Field Explorations – Runoff, Infiltration, and Transpiration

Lesson Summary

Through field explorations, students discover the multiple pathways that water takes after landing as precipitation on the urban landscape. The lesson starts with students brainstorming, then running field investigations to study runoff, infiltration, and evapotranspiration.

Purpose/Objectives

- To learn to observe and categorize land surfaces with respect to how water might move over and through them.
- To identify human infrastructure and other alterations that might affect water movement (storm drains, slopes, surfaces).
- To learn about infiltration and surface runoff and the factors that affect them.
- To learn about the process of transpiration and quantify the amount of water removed from the subsurface each year through this process.

Comp Hydro Learning Goals

C1 C5 D3 H7 H8

Next Generation Science Standards

MS-ESS2-4 HS-ESS3-6

Materials Needed

- Lesson 5-Water Pathways PowerPoint Presentation
- Aerial image of the schoolyard (example image)

Runoff Activity

- Narrow tray or gutter ("mud pan")
- Aluminum spray shield
- Shovel or hand trowel
- Large graduated cylinder
- Runoff on Slope Data sheet
- Water
- 2 Watering cans with spraying heads

Infiltration Activity

- Clear pvc pipe cut to 8 inches (see instructions)
- 8 inch long piece of 2x4 wood
- Hand trowel, timer, rubber mallet
- Infiltration data sheet and graph
- Water, Bucket, modeling clay

Transpiration Activity

- Gallon Ziploc bags w/ the zipper cut off
- Permanent marker, Duct tape, ruler
- Graduated cylinder
- Funnel Runoff on Slope Data sheet
- Water, Basin
- 2 Watering cans with spraying heads
- Loppers, scissors, Tree ID guide
- Graph paper
- Pencils

Agenda

Activity #	*Activity Label*	*Timing*	*Activity Description*
1	Brainstorming Water Pathways in the Schoolyard	5-10 min (less time if using the photo)	With an air photo or while exploring the actual schoolyard, students brainstorm water pathways in the school grounds.
2	Measuring Runoff on Schoolyard Slope	25 min	Students measure runoff on a schoolyard slope and discover the conditions that lead to fast vs. slow runoff.
3	Infiltration into Different Surfaces	35 min	Students measure the infiltration rates of different surface types in the schoolyard.
4	Transpiration	50 minutes (2-3 days setup/take down)	Students measure rates of evapotranspiration of different tree species using previously deployed transpiration bags.
5	Synthesizing Explorations	50 minutes or less	Students synthesize experiences from the explorations and make predictions about the vulnerability of their schoolyard to flooding.

Safety Concerns:
These activities take place outside. Prepare for extra staff to help supervise students in the schoolyard.

Activity One: Brainstorming Water Pathways in the Schoolyard

Activity Summary

Students will review different pathways water can take when it lands on the surface of the schoolyard.

Key Vocabulary

Water pathways
Flooding

Advanced Preparation

Download an aerial image of your school and school grounds from Google Earth or another free mapping site.

Materials Needed

- Lesson 5-Water Pathways PowerPoint Presentation
- Aerial image of the schoolyard (example image)

Activity Sequence

1. Begin this lesson with a review of the different pathways water can take when it lands on the surface of the schoolyard. With an air photo of the school and school grounds, or while exploring the schoolyard, brainstorm actual water pathways in the school grounds. Where does water striking the different parts of the schoolyard go? Then, show the Lesson 6_Water Pathways Presentation.

2. For the remainder of this lesson, students will explore water pathways in their schoolyard. Students should learn and understand that where water goes after a rainstorm matters and is directly influenced by the type of surface on which the water lands. Remind students that these pathways can lead to or prevent flooding in a given location.

Activity Two: Measuring Runoff on a Schoolyard Slope

Activity Summary

Students estimate the rate of simulated runoff from a slope in their schoolyard, then, calculate the rate of runoff per hour.

Key Vocabulary

Runoff
Precipitation

Advanced Preparation

Identify a suitable spot in the schoolyard for this activity. You want to locate a slope with a large enough angle that water will easily run down the slope. Consider pre-digging the trench to ensure the activity can be completed in one class period.

Materials Needed

- Narrow tray or gutter ("mud pan")
- Aluminum spray shield
- Shovel or hand trowel
- Large graduated cylinder
- Runoff on Slope Data sheet
- Water
- 2 Watering cans with spraying heads

Activity Sequence

1. Take students outside and locate an area of the schoolyard with an obvious slope.
2. Dig two small trenches at the base of the slope into which narrow trays or gutters are placed.
3. If available, place partitions (aluminum spray shields) in the soil to direct runoff into gutters. Fill watering cans with a measured amount of water.
4. Students will estimate the rate of simulated water from each watering can by flowing it into the basin for 1 minute. Calculate the rate of runoff per hour by 1) measuring the volume of runoff in the basin using a graduated cylinder or measuring depth of water directly in the basin, 2) calculate rate per hour - multiply the total amount of water by 60.
5. Use the first watering can to pour water down the slope at a slow rate. How much water ends up in the trench?
6. Use the second watering can to pour water down the slope at a fast rate. How much water ends up in the trench?
7. If the soil started out dry, repeat the slow precipitation rate treatment once the soil is wet to observe runoff when the soil is saturated (antecedent water). Did more or less water runoff into the tray when the ground was already wet? Why?

Runoff on Slope Data Sheet

Name: _____ Date: _____

Trial Description	Starting Amount	Time	Water in Basin	Runoff Ratio
Slow and dry	*100 ml*	*1 minute*	*50 ml*	*50%*
Slow and wet	*100 ml*	*1 minute*	*90 ml*	*90%*

Activity Three: Infiltration into Different Surfaces

Activity Summary

Students use an infiltrometer to measure the rate of infiltration for at least two different types of surfaces. Students graph their data and assess the infiltration potential in their schoolyard.

Key Vocabulary

Infiltration
Infiltrometer
Permeability

Advanced Preparation

If needed, identify an additional staff person to help supervise students outside. Ensure you have enough materials for each group to work independently.

Materials Needed

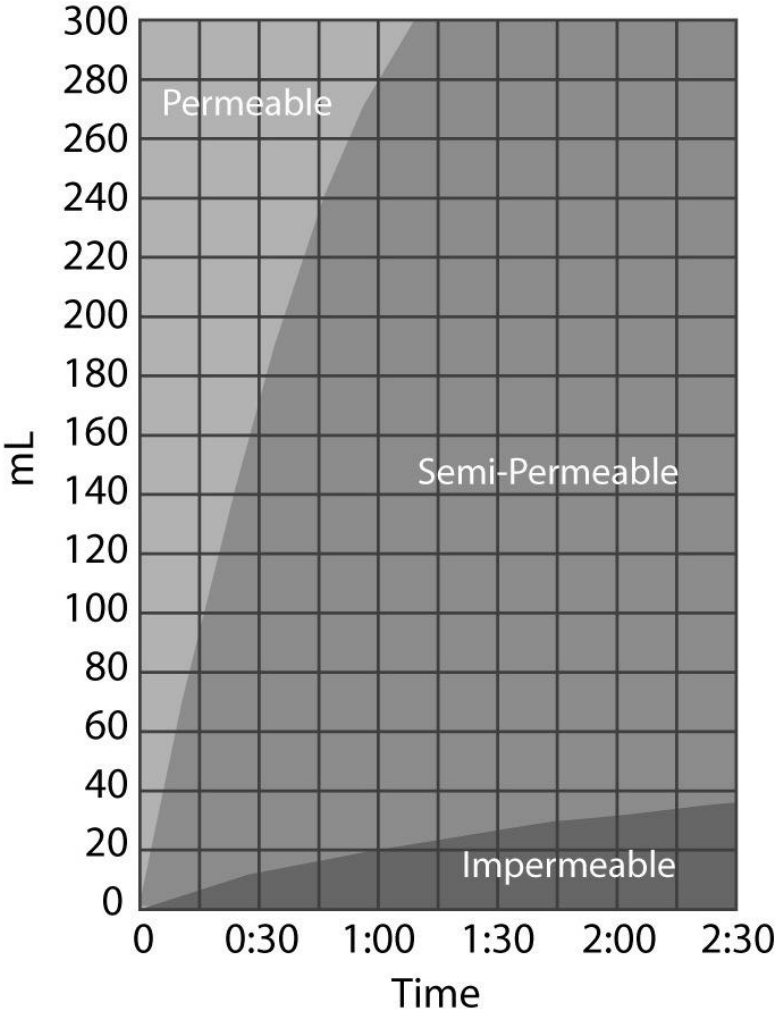
- Clear pvc pipe cut to 8 inches (see instructions)
- Rubber mallet
- 8 inch long piece of 2x4 wood
- Hand trowel, timer
- Infiltration data sheet and graph
- Water, Bucket, modeling clay

Activity Sequence

1. Place the infiltrometer on the surface you want to test and make a good seal. In sand or loose soil, simply push the tube into the ground. In hard packed soil or gravel, you may need to twist, push harder, or wet the soil a tiny bit. Use the wood block and mallet to bang the infiltrometer into the ground. Make sure all loose gravel and stones are removed from beneath the infiltrometer or it will crack. On concrete, asphalt, or roofing shingles you will need to create a seal with a 25 cm long 'snake' made out of modeling clay. The snake should be about 1 cm in diameter. Place the clay along the bottom of the infiltrometer and press firmly to the ground. Smooth the clay out to make a good seal between the infiltrometer and surface of the ground.
2. Find a spot on the ground that is smooth and free of plants. Group students in teams of 3 or four and assign roles. 1) pour the water, 2) timekeeper, 3) data recorder, 4) scale reader.
3. Use the bucket of water to fill the infiltrometer up to the 0mL mark then quickly start the stopwatch. Every 15 seconds, read and record the water level.
4. Plot your results on the graph below.
5. Repeat test on at least two different types of surfaces. Ensure that each surface is tested at least three times. Talk to your students about the importance of replication.
6. Have students rank their three surfaces by permeability and share with the class.
7. To create a nice class visual, use a large sheet of poster paper and draw an x and y axis with labels for time and mL of infiltration. Have each group graph all their data on this one sheet using different colored markers for the different surface types.

Infiltrometer Data Sheet

Surface #1		Surface #2		Surface #3	
Description		Description		Description	
Time	mL	Time	mL	Time	mL
0:00	0	0:00	0	0:00	0
0:15		0:15		0:15	
0:30		0:30		0:30	
0:45		0:45		0:45	
1:00		1:00		1:00	
1:15		1:15		1:15	
1:30		1:30		1:30	
1:45		1:45		1:45	
2:00		2:00		2:00	
2:15		2:15		2:15	
2:30		2:30		2:30	



Ranking of Permeability

Least Permeable

Most Permeable

Activity Four: Transpiration

Activity Summary

Students create a hypothesis about trees and transpiration, then, design an investigation to test their hypothesis using Ziploc bags, duct tape and schoolyard vegetation. Students carry out their investigation in the schoolyard.

Key Vocabulary

Watershed
Precipitation
Stream gauge
Photosynthesis
Transpiration

Advanced Preparation

This activity requires the use of woody vegetation with leaves. You can conduct this investigation with a potted plant; however, the results will be difficult to translate into schoolyard transpiration. Consider starting this activity on a Friday and completing the following Monday to allow the transpiration bags a full two days (more is better) to capture water.

Materials Needed

- Gallon Ziploc bags with the zipper cut off
- Permanent marker
- Duct tape
- Graduated cylinder
- Funnel
- Loppers
- Scissors
- Tree ID guide
- Graph paper
- Pencils

Activity Sequence

1. Review the key ideas about leaf functions: a) absorb sunlight for photosynthesis, b) take CO2 from the air through their stomates, c) CO2 enters the leaf tissues/cells by dissolving into water in cell walls surrounding the cavity in the leaf inside the stomates, d) water evaporates from these wet cell walls (inevitable), e) water (and O2) leave the leaf through the stomates, and f) the CO2 and sunlight, plus water, are used to make sugar via photosynthesis inside the leaf cells. Discuss what factors might determine how much water evaporates (transpires) from leaves.
2. As a class, agree on a hypothesis about trees and transpiration. For ex: maple trees transpire more than oak trees or leaves in the sun transpire more than leaves in the shade.
3. Design an investigation to address the hypothesis. Decide on how many replicates of each condition you will use (e.g., how many maple and oak branches you will study).
4. Prepare the required number of gallon Ziploc bags (plus a few extra) by cutting off the zipper and labeling each bag with a sharpie marker with an appropriate identifier.
5. Go outside and find a tree or set of trees with which to test your hypothesis.
6. For each replicate or sample, place a baggie over the end of a branch, approximately 6 inches, so it fits in the bag without crowding or bending the branch. The bag should include no more than 3 to 6 deciduous or 100 or so needles. Bunch the open end of the bag around the branch and use duct tape to tightly seal it around the stem. You might have to remove some leaves or needles where you attach the duct tape to make a tight seal. Also, make sure the top of your baggie is higher than the bottom to prevent leaks.
7. Optional: Measure the radius of a circle on the ground that represents the area covered by the crown (leaves) of the tree for each tree you study. Record in column E in datasheet.
8. Return to the tree two or three days later and cut off the branch with loppers or scissors just above the bag and carry the branch with the bag still attached inside for processing.
9. Measure and record the volume of water collected in each bag in column B. Use a funnel and graduated cylinder, being careful to retrieve all the water from the leaf surfaces and inside of the bag

Safety Concerns: Be sure students avoid touching poison ivy or poison oak.

Continued: Transpiration

10. Determine and record the total leaf area of all of the leaves in each bag. Place the leaves on top of a piece of graph paper and trace the outline of each leaf on the graph paper. Count the number of squares that make up each leaf. Measure the size of the graph paper grid squares and then calculate the surface area of each leaf in the bag. Record in column C.
11. Calculate the transpiration rate (in ml/cm2 day) for each branch by dividing the volume of water loss by the leaf area and number of days the bags were on the branches. Record in column D. Use your data to address your hypothesis.
12. OPTIONAL: Estimate per-tree transpiration rate. This will give you an estimate of the daily amount of water the tree uses based on your measurements.
    a. Calculate the area of each tree crown using the radius you measured for each tree in the field.
    b. Multiply the daily transpiration rate you calculated by 3.92 leaf area / ground area to get an estimate of per-ground area daily transpiration rates. 3.92, called the Leaf Area Index, is an estimate of the typical amount of leaf area per ground area in a healthy tree. You can visualize this by imagining all the leaves of a tree squeezed down onto the land surface. For deciduous forests in our area, this would result in a carpet just under 4 leaves thick on the ground.
    c. Multiply this number by the ground area / tree crown you calculated for the tree from the radius measured in the field. Record in column F.
13. OPTIONAL: Estimate the total seasonal transpiration rate. This will give you an idea of how much transpiration takes place over an entire season based on the rate you measured.
    a. Estimate the number of days in the growing season in your area.
    b. Multiply this number by the daily transpiration rate per ground area that you calculated above (in column D).
    c. Compare this amount to the annual precipitation rate to get an idea of how much of the annual water budget leaves the land via transpiration.

Transpiration Worksheet

Names of Students: _____

Start date: _____ End date: _____ # of days bags were on branches ____

1. Hypothesis about trees and transpiration:

   _____

   _____

   _____

2. Brief description of methods used to test hypothesis. What 'treatments' or 'factors' will you be comparing (for example tree species or locations)?

   _____

   _____

   _____

3. Fill in the datasheet for each bag. Add lines if needed.

Bag	A. Treatment or Factor	B. Volume of Water Collected	C. Total Leaf Area	D. Transp. Rate (ml/cm2-day, or mm/day)	E. Radius of Tree Crown (cm)	F. Per Tree Transp. Rate	G. Per Season Transp. Rate (Depth)
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

4. Make a claim addressing your hypothesis based on your findings in column D.

5. If you calculated per tree transpiration rates (column F), how do these compare to the amount of water used by the average US citizen each day of 100 gallons?

6. If you calculated the growing season depth of water used by the tree (column G), how does this compare to the annual precipitation for Baltimore of approximately 100 cm?

Activity Five: Synthesizing the Explorations

Activity Summary

Students review the results of the activities and their observations on runoff, infiltration and transpiration, then, create a diagram identifying and describing the different pathways water can travel in the schoolyard. Finally, students make suggestions to their principal for ways the school can increase infiltration in the schoolyard.

Key Vocabulary

Infiltration
Runoff
Transpiration

Advanced Preparation

None

Materials Needed

- Lined paper (students will need to answer questions on a separate piece of paper)
- 2 sheets of blank unlined paper per student for conceptual models
- Results from the 4 previous activities
- Synthesizing the Explorations worksheet

Activity Sequence

1. Ask students to review the results of each of their activities and talk with a neighbor about observations they made about runoff, infiltration and transpiration.
2. Next, ask a few students to share what they discussed with the entire class. Does everyone agree with what these students shared? Do some students have different results or understanding of the results? If so, discuss these differences.
3. As a class, complete a diagram about the different water pathways studied in the lesson. The structure of the diagram is similar to what they completed during Lesson 1 and asks students to describe the causes and consequences of the three water pathways they studied. The diagram students create should include the following components:
   - I. Infiltration
     - a. Causes
       - i. Conducting pathway – pore spaces in soil, particle surfaces
       - ii. Driving forces – gravity, surface attraction
     - b. Consequences
       - i. Water enters the soil - is either taken up by plants, stored or continues to move down towards the water table.
   - II. ii) Runoff
     - a. Causes
       - i. Conducting pathway – soil surface
       - ii. Driving forces – gravity, surface attraction
     - b. Consequences
       - i. Water runs down slopes rather than infiltrating into the ground.
       - ii. Water collects in low spots on the landscape (streams or storm drains)
   - III. iii) Transpiration
     - a. Causes
       - i. Conducting pathway – stomata, leaf epidermis
       - ii. Driving forces – heat, gradient of water concentration from wet leaf to dry air
     - b. Consequences
       - i. Water returns to atmosphere as H_2O gas
       - ii. Water is drawn up to tree leaves from stems and roots, ultimately from the soil
4. Students now complete the Lesson 6 Activity 5 Synthesizing Explorations worksheet.
5. At the end of the lesson, collect student letters to read and make a decision about how they will be delivered.

Synthesizing Explorations Worksheet

Name:_____ Date:_____

1. Now that you've observed where water striking different parts of the school grounds goes, make a claim about how much of a summer time rain fall might move along the three different pathways – runoff, infiltration and transpiration. Use evidence from your explorations to support your claim.

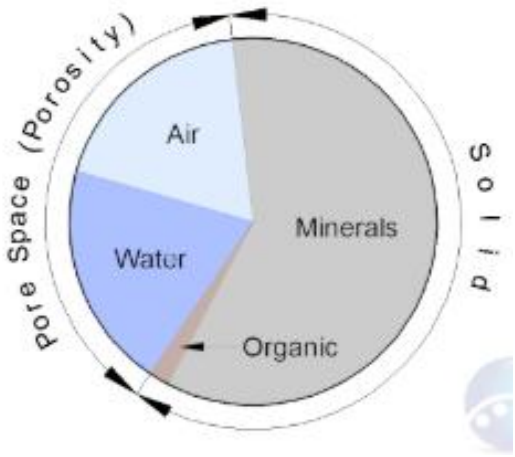
2. How might knowing information about evapotranspiration and soil moisture of an area help city planners?

3. On a separate piece of paper or on your computer, write a short letter to your principal with suggestions for how to reduce runoff on your school's campus. Include the following in your letter:
    a. A brief description of the Explorations you completed during this lesson
    b. A summary of the data results for each of the Explorations
    c. Your suggestions for how to reduce runoff on the school's campus
    d. Evidence from the Explorations that your suggestions will actually reduce runoff on the school's campus. *For example: We found that the rate of infiltration in the mulched gardens was higher than on the lawn. Therefore, we suggest creating more garden spaces on campus.*

Teacher Resources

1. Runoff & Infiltration background: https://study.com/academy/lesson/runoff-infiltration-definition-process.html or; https://www.usgs.gov/special-topic/water-science-school/science/runoff-surface-and-overland-water-runoff?qt-science_center_objects=0#qt-science_center_objects
2. Infiltration and the Water Cycle: https://www.usgs.gov/special-topic/water-science-school/science/infiltration-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects
3. Porosity Values for Various Soil Types:

https://structx.com/Soil_Properties_006.html



Description	Porosity
Sand; Coarse	0.26 - 0.43
Sand; Fine	0.29 - 0.46
Sand/Gravelly Sand; Well Graded; Little to No Fines	0.22 - 0.42
Sand/Gravelly Sand; Poorly Graded; Little to No Fines	0.23 - 0.43
Silty Sands	0.25 - 0.49
Clayey Sands	0.15 - 0.37
Inorganic Silt/Silty Sand; Slight Plasticity	0.21 - 0.56
Gravel	0.23 - 0.38
Gravel/Sandy Gravel; Well Graded; Little to No Fines	0.21 - 0.32
Gravel/Sandy Gravel; Poorly Graded; Little to No Fines	0.21 - 0.32
Gravel/Silty Sandy Gravel	0.15 - 0.22
Clayey Gravel/Clayey Sandy Gravel	0.17 - 0.27
Inorganic Silt; Uniform	0.29 - 0.52
Clay/Silty Clay/Sandy Clay; Low Plasticity	0.29 - 0.41
Organic Silt/Silty Clay; Low Plasticity	0.42 - 0.68
Silty Clay/Sandy Clay	0.2 - 0.64
Inorganic Silt; High Plasticity	0.53 - 0.68
Inorganic Clay; High Plasticity	0.39 - 0.59
Organic Clay; High Plasticity	0.5 - 0.75

4. Article: *Student ideas about computational thinking concepts when learning about modeling and hydrologic systems*: http://ibis-live1.nrel.colostate.edu/CompHydro/public/Publications/Paper2_Computational_Thinking.pdf