Lesson 3: How Deep Will It Flow?

Lesson Overview:

Purpose: This activity will help students understand how much water soil can absorb and how this information is used to predict how big you should size a rain garden.

Background:

Soils vary greatly in fertility, drainage, and pH. It is best to understand what kind of soil is on the school site and put in a rain garden suitable to the conditions at that site. If you are uncertain about the kind of soil at your site, - you can have your soil tested or invite a professional to evaluate the soil. Another method is to use soil keys included with this lesson to evaluate the soil yourself.

Soil is a critical component of a rain garden because the soil type and porosity determine whether or not a rain garden will drain properly and support the plants growing in it. It is important for rain gardens to have well drained soils so that any runoff that drains into the garden either soaks into the ground and/or transpires back into the atmosphere within 24-48 hours. If water sits in the rain garden longer than 48 hours, it may harm or kill plants growing in the garden and/or allow mosquitoes to breed.

According to the United States Department of Agriculture, soil scientists have identified over 70,000 kinds of soil in the United States. The USDA and local Soil and Water Conservation Districts maintain maps of soil types and make this information available to the public. This type of information is very useful when planning your rain garden because it will help you determine how to amend your soils if necessary. Check your local phone book for a Soil and Water Conservation District Office near you.

On average, **soil** contains 45 percent minerals (sand, silt and clay), 25% water, 25% air, and 5% organic matter. Different-sized mineral particles, such as sand, silt, and clay, give soil its texture. **Sand** is between 0.05 – 2.00, silt is between 0.002 – 0.05 and clay is smaller than 0.002 millimeters in size. **Organic matter** helps soil retain moisture and can improve drainage in poorly drained soils. Soil texture can be determined by feel using a dichotomous key developed for this purpose. **Soil keys** require one to take about 2 teaspoons of moistened soil rub soil between their fingers until it turns into a ribbon of uniform thickness and width.

Sand has a gritty texture, silt has a texture similar to flour, and clay particles are sticky and clump easily. Soil also contains organic matter such as decaying plant and animals and this also contributes to the soils texture and ability to retain water. **Soil types** include sand, loamy sand, sandy loam, sandy clay loam, sandy clay, loam, clay loam, clay, silty loam, silty clay loam, and silty loam.

Another way to determine soil type is to use a settling cone. In a **settling cone**, a known volume of soil and is mixed with water until the soil is completely suspended in the liquid. Let the cones are allowed to sit until all of the soil settles to the bottom. The heaviest materials such as sand and gravel will settle out first followed by silt and clay. The layers are measured to determine the percentage of clay, sand, and silt and this is used determine soil type. You can make home-made settling cones from 2 liter bottles and this method is described in this lesson. A simpler version of the settling cone is the “Soil Shake” method described in this lesson.

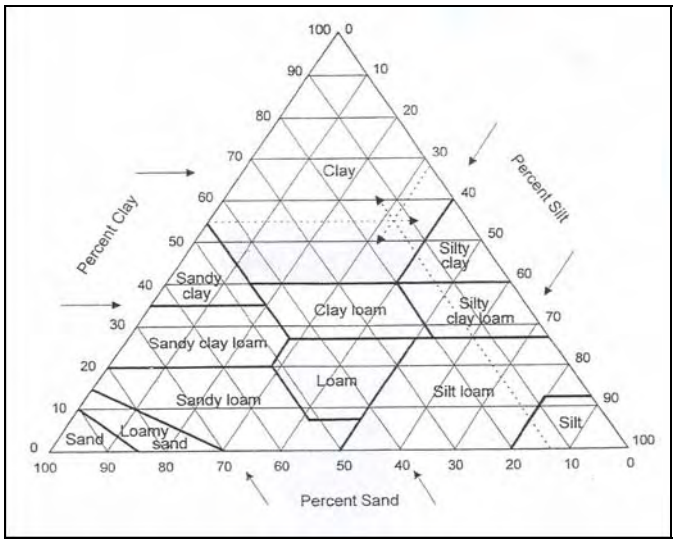
Soil texture determines the soil's porosity because it dictates how much space there is between the particles. The spaces between particles are usually filled with air or water depending on weather conditions. For example, if soil is sandy, it will drain quickly. If soil has a lot of clay, it may drain poorly. The rate water passes through soil is called the **percolation rate**. In a rain garden runoff needs to percolate through the soil at least 0.5-1.0 inch per hour. To conduct a **percolation (perk) test**, make a hole 8 inches in diameter and 8 inches deep. Fill the hole with water and let it drain. Then refill the hole with water and use a pencil to mark the top of the waters surface. Time how long it takes for the hole to drain and measure the inches from the pencil to the bottom of the hole. The measurement is reported in inches per hour. It is desirable to have a perk test result of 0.5 – 1 inch per hour. The perk test result is used to determine the depth of the rain garden. To determine the depth of the garden, use this formula:

$$\frac{\text{? inches}}{\text{? hours}} \times \frac{\text{24 hour}}{\text{1 day}} = \text{? inches per day}$$

If the soil drains 0.5 inch per hour, the rain garden should be no deeper than 12 inches (0.5 x 24). If the soil drains 0.25 inches per hour the garden would be no deeper than 6 inches (0.25 x 24). A result of 1 inch per hour would mean the rain garden could be up to 24 inches deep. Most residential rain gardens are between 8 – 12 inches deep and less than 400 square feet in size. Larger rain gardens usually do not exceed 18 inches deep.

If the perk test shows that your soil only drains less than 0.5 inch per hour, the soil may need to be amended to improve drainage. The more clay in the soil, the slower the soil will drain. Rain Garden Experts across the US differ about how to amend soil to improve drainage. There are two ways to amend soil: organic matter and inorganic matter. Organic matter includes compost and mulch. Inorganic matter includes various sizes of sand and even gravel. Most professionals recommend amending existing soil in residential rain gardens by adding various percentages of organic matter and/ or inorganic matter. Recommendations vary from 50-50 existing soil and compost to 30-30-30 existing soil, compost, and sand to 25-50-25 existing soil, sand, and compost. To determine what will work best, conduct a soil amendment test using settling cones before amending the bed. To determine the porosity of amended soils, mix various percentages of existing soil, compost, and sand and put this mixture into a settling cone. If you do not have a settling cone, it is easy to make one. To make a home-made settling cone, cut off the top of 2 liter bottle 2/3 of the way down from the neck or screw top, inverting this section and place it into the 1/3 section. Then fill it with the amended mix, tamp the soil mixture down to mimic actual soil conditions, and pour water through it to get the soil settled and ready for the test. Then time how fast each column drains. Ideally you want a result 0.5-1 inch per hour.

Soil Pyramid



Source: USDA

Lesson Descriptions:

Option 1: Elementary School

Objectives: Students will:

1) Describe what soil is and list the components found in soil (sand/gravel, clay, organic matter);
2) View soil types using a 10X microscope or hand lens;
3) Calculate the percentage of sand/gravel, clay, and organic matter in soil using a simple settling cone activity called "Soil Shakes;
4) Define the term soil porosity and demonstrate the porosity of several soil types;
5) Conduct an experiment by mixing soil components to determine which soil mix has the best porosity;

Topics Covered: Sand, Silt, Clay, Organic Matter, Soil Types, Soil Keys, Soil Texture, Porosity, Percolation Rate, Soil Pyramid, Experimental Design

Activity Time:

1 class period

State Standards: (See Appendices – Rain Garden Lesson Guide Correlations by Grade)

Materials:

Soil from school site
Microscope or 10x hand lens
Small Petri dishes or slides
Paper
Crayons or colored markers
1 liter or quart clear containers with lids
Water
Measuring Cup
Watch with second hand
Ruler

Follow Up

Other soils from around the area

Extension

Commercial indoor potting mix
Commercial cactus potting mix
Foam or plastic cups
Scissors or ice pick to make holes in cups
Measuring Cup
Masking Tape
Permanent marker or ink pen
Water
Data sheet

Introduction:

Give each student a small clump of soil and have them examine the soil type by rubbing it between their fingers. What did they notice about the soil? Have students describe what soil is and what components are found in soil (sand/gravel, clay, organic matter). Then have them look at different types of soil using a microscope with a 10X power lens. Now they are ready to conduct an activity to find out what ypes of soil they have at their school and calculate the percentage of sand/gravel, clay, and organic matter in soil using a home-made settling cone activity called "Soil Shakes." They are going to see how porous different soils are and compare them to the soil at your school. Finally they are going to get a chance to blend their own soil mix to test its porosity.

Hands On:

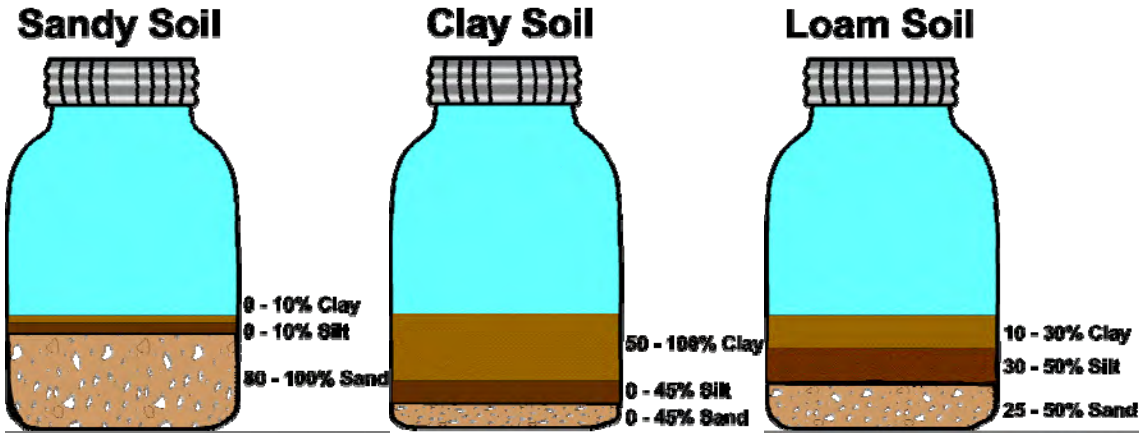
1) Take a clump of soil and spread a thin layer of this soil onto a small dish and put it under the 10X power on a microscope or use a 10X hand lens to view it. What did they see? Have them draw a picture of what they saw and label the picture. They should be able to see particles of different sizes and colors.

2) Have the students feel the soil and use information in the table below to determine soil types:

Sand	Sand particles are the largest and heaviest soil particles. Sand also has larger spaces between particles, and so is less compact than clay or silt. Sandy soils feel gritty to the touch. Sand is porous and usually holds less water for plants and animals than other soil types. Soils with large amounts of sand can dry out easily and are not as useful for growing most plants.
Silt	Silt particles are of middle size and weight. Silt feels smooth and slippery to the touch when wet. Silty soils hold both nutrients and water well, which can make them good soils in which to grow plants.
Clay	Clay particles are the smallest and lightest soil particles. Clay soils are generally highly compact, with little space between particles. This can make it difficult for many plants to thrive in soil containing a high level of clay, since it is harder for roots to grow and for circulating air to reach the roots. Clay feels sticky to the touch when it is wetl but can harden and crack

	when it gets dry and hot. Clay also tends to hold more water.
Organic Matter	Organic Matter is very light and tends to float to the top. Organic matter comes in a variety of sizes and colors. Organic matter feels like little sponges. Organic matter is comprised of dead plant and animals and adds nutrients back into the soil when it decomposes. Because organic matter decomposes over time, it must be replenished.

3) Have students they are going to make a "Soil Shake."
   a) Divide up into teams of 2-4 and give each team a two liter clear soda bottle, a measuring cup, and a trowel, and a ruler. Have the students fill their soda bottles 2/3 full with water. (Optional: add ½ teaspoon of water softener or ¼ teaspoon of dish soap to help the layers settle out better). Have them go outside and using a trowel to dig up soil from their proposed rain garden location and place it into a bucket. When they return to the classroom, they are going to measure out the soil and water, add the soil and water to the container, put the lid back on, and shake their bottles vigorously for 2 minutes to completely mix up the soil.
   b) The next day, measure the soil layers. Review the components of soil: sand, silt, clay, and organic matter (see table below). Have students observe the demonstration. What did they see? (layers) Which layer is which? (bottom layer is sand, next layer is silt, next layer is clay, and top layer is organic matter) Measure each layer. Which layers are the biggest? The Smallest? What kind of soil do you think you have? If the layers are fairly equal, it is a loamy soil. If the clay layer is the largest, it is a clay-type soil. If the sand type is largest it is a clay type soil. (See Soil Pyramid illustration in Background Section.)



Follow-up: Have students repeat the Soil Shake Experiment and compare other soils from different parts of the county or from home. Or test commercially available soil mixes like potting soil and cactus mix. Create known samples to see if the results match the percentages of the mixes. For example: mix ¼ sand/.¾ clay; ½ sand/½ clay; and/ or ¾ sand/¼ clay. When the mixture settle out, are the percentages the same? Why or why not?

Extension: Have the students test two or more soil mixes to see which soil type is the most porous? For example, use known mixes like ¼ sand/ ¾ clay; ½ sand/ ½ clay; and/or ¾ sand/ ¼ clay. Or use soil from your school site and add know quantities of sand or compost to the school site soil. Divide the students into teams and give each team 2-3 sixteen once foam or plastic cups with 10 drain holes punched in the bottom of the cup and 2-3 cups with no holes. Have them place the cup with the holes in it into the other cup. Then place 1/2 cup of a soil into the top cup. Use masking tape to label the cups with the type of soil in the cup. Then pour 1/2 cup of water into the cup and wait for the water to completely drain from the upper cup. Time how long this takes and record it on a data sheet. Then measure the amount of water that came out. Record your results. Which soil drained faster and which drained slower? Why? Which soil held the most water? Why? Observe the mixes as they dry out. Which one dried faster, slower, and why? How might this affect plants in the rain garden?

Option 2: Middle School

Objectives: Students will:

1) View soil types using a 10X microscope or hand lens;
2) Calculate the percentage of sand/gravel, clay, and organic matter in soil using a simple settling cone activity called "Soil Shakes;"
3) Define the term soil porosity demonstrate the porosity of several soil types;
4) Conduct an experiment mixing soil components to determine which soil mix has the best porosity;
5) Use perk test information to calculate optimum depth for rain garden; and
6) Research what soil type(s) occur on their school site.

Topics Covered: Sand, Silt, Clay, Organic Matter, Soil Types, Soil Keys, Soil Texture, Porosity, Percolation Rate, Perk Test, Soil Pyramid, Experimental Design

Activity Time:

1-2 class periods

State Standards: (See Appendices – Rain Garden Lesson Guide Correlations by Grade)

Materials:

Soil from school site
Key to Soil Texture by Feel (appendices)
Microscope or 10x hand lens
Teaspoon measure
Key to Soil Texture by Feel
Water
2 liter bottles
Window screen, cheese cloth, or paper towels (2" x 2")
Pencil or popsicle sticks
Scissors or box cutter
Measuring cups
Sand
Compost
Top Soil
Soil from School Site
Masking Tape
Permanent marker or ink pen
Watch with second hand
Soil moisture probe (optional)

Follow Up

Same as Hands On

Extension

Same as Hands On

Introduction: Give each student a small clump of soil about the size of a fist. Ask them to examine the soil by rubbing it between their fingers. What did they notice about the soil? Have them use all of their senses to describe the soil. What components are found in soil (sand/gravel, clay, organic matter)? Use a **Key to Soil Texture by Feel** (see Appendices) to determine what type of soil they have. Then they are going to conduct an experiment to see how porous different soils are and compare them to the soil at the school. Finally they are going to blend their own soil mixes to test its porosity.

Hands On:

1) Have students work their soil clump in their fingers and examine it with a hand lens. Based on the feel and look of the soil, have them guess what kind of soil sample they have? Hand out a copy of the **Key to soil Texture by Feel** charts to each student or team of students. Have the students measure 2 teaspoons of soil from their clump and to add water drop by drop, kneading the soil until it is moldable and feels like moist putty. Then have them follow the directions on the soil key until they determine the soil type. Did they guess correctly? Did everyone get the same answer? Why or why not?
2) Have the students compare various soil mixes to determine which would work best for a rain garden. Take several 2-liter bottles and cut the bottom 1/3 of the bottle off. Place a square piece of window screen, cheese cloth, or paper towle in the bottom of the 1/3 section, turn the 2/3 portion with the bottle neck upside down and nest it in the bottom half of the bottle. Then use a Popsicle stick to separate the two halves of the 2-liter bottle model to allow for air flow (see picture included). Now you are ready for your experiment. Put 2 cups of soil from your school site in the first bottle, tamp the soil down to mimic natural conditions, and pour 1 cup of water through it. Decide as a group what proportion of sand, compost, and topsoil you think would work best for a rain garden and place it into the second bottle. Then put another combination in the 3rd bottle. Your mix should equal 2 cups. Record how much of each component on a piece of masking tape and label each bottles. For example: 1 cup compost/ 1 cup native soil. Make sure you tamp the soil mixes down to represent natural conditions and allow 1 cup of water to pass through them before you start the experiment.

Remind the students that the soil has to drain at least 0.5-1.0 inch per hour to work for a rain garden. Assign one person to be the time keeper and another to add 2 cups of water to each bottle. Time how long it takes for the two cups to drain. Some mixtures will drain quickly and other will take hours. After you pour in the water, place a piece of masking tape with the word start on the bottle to show the top of the water at the start of the experiment. If it drains quickly, place a piece of tape with the word stop and the time it took for the water to drain to the top of the soil. For mixtures that take longer, every hour, take another piece of marking tape and mark how far the water has gone down in the bottle on the container. Repeat this procedure until all of the bottles are drained. Which mix worked best? Which ones drained in 24 hours? NOTE: The soil depth in this simulation is about 4 inches deep ad most rain gardens are 6-12 inches deep. To mimic natural condictions you would need to creat models that are deeper ro exprapolate using the 4 inch data. For example, if the soil is 4 inches deep and it drained 1 hour,, and the rain garden weas 12 inches deep, it would take about 3 hours to drain. Record the soil moisture at when each soil is drained. Then set the bottles aside and record soil moisture the next day with a soil probe. Repeat for 3-4 days. Which soil remained moist and which dried out? How do you think this might affect the rain garden plants?

Follow-up Repeat the above demonstration and pour 2 more cups of water into the saturated soil to represent a rainy period of several days. Then record how much drained every hour? How did the saturated soils compare? Did they drain in 24 hours? If not how would you modify your mix?

Extensions: Have the students repeat the percolation test by modifying the soil from their school site to determine the best soil mix for their site under saturated conditions.

Option 3: High School

Objectives: Students will:

1) View soil types using a 10X microscope or hand lens;
2) Calculate the percentage of sand/gravel, clay, and organic matter in soil using a simple settling cone activity called "Soil Shakes;"
3) Define the term soil porosity and demonstrate the porosity of several soil types;
4) Conduct an experiment mixing soil components to determine which soil mix has the best porosity;
5) Conduct a simple perk test to determine the porosity of the soil in the schools proposed rain garden;
6) Use perk test information to calculate optimum depth for rain garden;
7) Research what soil type(s) occur on their school site; and
8) Experiment with the fertility of various rain garden soil types.

Topics Covered: Sand, Silt, Clay, Organic Matter, Soil Types, Soil Keys, Soil Texture, Porosity, Percolation Rate, Perk Test, Soil Pyramid, Experimental Design

Activity Time:

1-3 class periods

State Standards: (See Appendices – Rain Garden Lesson Guide Correlations by Grade)

Materials:

Key to Soil Texture by Feel (optional)
Trowels
Rulers
Popsicle Sticks
Index Cards
Pencils with erasers
Watch with second hand
Water
Sprinkling Can or hose
Calculator
2 liter containers
Window screen, cheese cloth or paper towels – 2" x 2" square
Sand
Compost
Soil from School Site
Measuring Cup
Masking Tape
Permanent markers or ink pens

Follow Up

2 liter containers
Sand
Compost
Soil frpm School Site
Measuring Cup
Masking Tape
Soil Moisture Probes
Permanent markers or ink pens
Plant plugs of same plant variety
Digital Camera

Extension:

Nine 2 liter bottles
Soil Moisture Probes
Plant Plugs of 3 different varieties
Measuring cup
Water
Fertilizer

Introduction

To introduce this lesson, give each student a small clump of soil about the size of a fist. Ask them to examine the soil by rubbing it between their fingers. What did they notice about the soil? Ask them to describe what soil is and tell you what components are found in soil (sand/gravel, clay, organic matter). Ask them to research what types of soil are found near their school site. Local Soil and Water Conservation Districts (SWCD's) are a good resource for soils information. Optional: Have students use the Key to Soil Texture by Feel. Did their results agree with SWCD Maps? Tell them that they are going to conduct an Infiltration Test or Perk Test on the soil at their proposed rain garden site. Based on their Perk Test results, they are going to experiment with the porosity of various soil blends to determine which blend is the best for their school site. They are going to test each blend for percolation rate in dry and saturated conditions, soil moisture over time after rain events, and how well a plant grows in the mix. Using these results they will select a soil blend for their rain garden site. Finally, they will re-calculate the rain garden size using the perk test results and compare them with their slope information.

Hands On:

1) Divide the class into teams of 2-4 people and give each team a trowel, ruler, popsicle stick, index card, pencil with eraser, and make sure each team has a watch. If there is no water source, fill several large buckets with water and have the teams share them. If there is a water source, take unfilled buckets with you. Then take the class to the proposed rain garden site, and have each team dig a hole 8 inches wide and 8 inches deep. Use the ruler to measure the width and depth of the hole. Then have them fill their hole to the top with water and let the water completely drain. When it is drained have them re-fill the hold and use a Popsicle stick or pencil to mark the top of the water level.

2) Record the time. Then wait 15 minutes and measure from the Popsicle stick to the top of the water. Repeat every 15 minutes until the hole is drained. In heavy clays you may need to repeat this every hour instead of every 15 minutes. You want to calculate the amount of water that drains in 24 hours so you will use this conversion:

   a. $\frac{\text{? inches}}{\text{? hours}} \times \frac{\text{24 hours}}{\text{1 day}} = \text{? inches per day}$

   For example, if the perk test drained 1 inch in 4 hours the result would be 6 inches in 1 day (or 24 hours)

3) Using the perk test results instead of the slope results, re-calculate the rain garden size from the ***Capture Store and Release*** High School Option Hands On Step 5.
4) Have students conduct the ***How Deep Will It Flow*** Middle School Option Hands On Step 2 but have the students teams test more options and the record results.

Follow-up: Pick the best 3 soil mixes. Place the saturated models in a sunny window and wait 1-2 days to dry out a little. Establish a pattern of recording soil moisture every day for the duration of the experiment. Plant a plug of the same rain garden plant in each container. Record the soil moisture and take a picture. Then allow the plants to grow. Water the model with ½ cup of water the first and second week to allow the plants to establish. Take a picture every time you water the plants. Then water the models with 2 cups of water the 3rd week and let them drain. Wait one week and water ½ cup on the 4th week. Then repeat the following week with 2 cups on the 5th week. Finish with ½ cup on the 6th week. Record the performance of the plants in photos and measure heights. After 6 weeks, make a graph of the soil moisture noting when you added water and how much.

Extensions:

1) Demonstrate the difference in plant performance within different zones of the rain garden using the same soil type and 3 types of plants. Make up 9 Soil Infiltration columns using 2 liter bottles and put the same soil mix in these containers as you plan to use in your rain garden. Label the containers “Edge Habitat,” 3 containers as “Middle Habitat,” and 3 containers as “Wet Habitat.” Use 3 different plants, one that prefers dry conditions, one that prefers evenly moist, and one that can survive inundation. Then plant one of each plant in each of the 3 sets. Allow the plants to acclimate in the containers for 2 weeks watering them about 1 cup per week. Then water the dry habitat with ½ cup of water, the middle habitat with 1 cup of water, and the wet habitat with 2 cups of water every week for the next 4 weeks. Take photos each time you water and soil moisture readings every day. Did the plants perform well for their type in the soil mix? Take a look at the soil moisture readings. Are the plants wicking out the moisture?
2) Repeat the above experiment, but fertilize the plants when you plant them. Did this make a difference?