Lesson 2: Capture, Store and Release

Lesson Overview:

Purposes: To help students understand:

1) how much water actually runs off the land after storm events,
2) how the porosity of the lands surface influences runoff volumes,
3) how to calculate the storage capacity needed for a rain garden using drainage areas and precipitation; and
4) how the size and shape of the rain garden traps and stores water that is either conveyed to underground aquifers or transpired into the atmosphere by plants.

Background:

Whether or not water soaks into the ground or runs off the ground is determined by how porous the land is, how saturated the soils are, the slope of the land, and the size and duration of storm events. In a natural undeveloped environment, approximately 50 % of the rain will be absorbed by the soil, 10 % of rain will run off into local water ways, and 40% will transpire back into the atmosphere. When you increase impervious surfaces by 35-50% which is similar to the conditions found urban residential neighborhoods, it changes to 35% absorption, 30% runoff, and 35% transpiration. In larger urban cities where impervious surface can range between 75 – 100%, 15% is absorbed, 50% runoff, and 30% transpires.

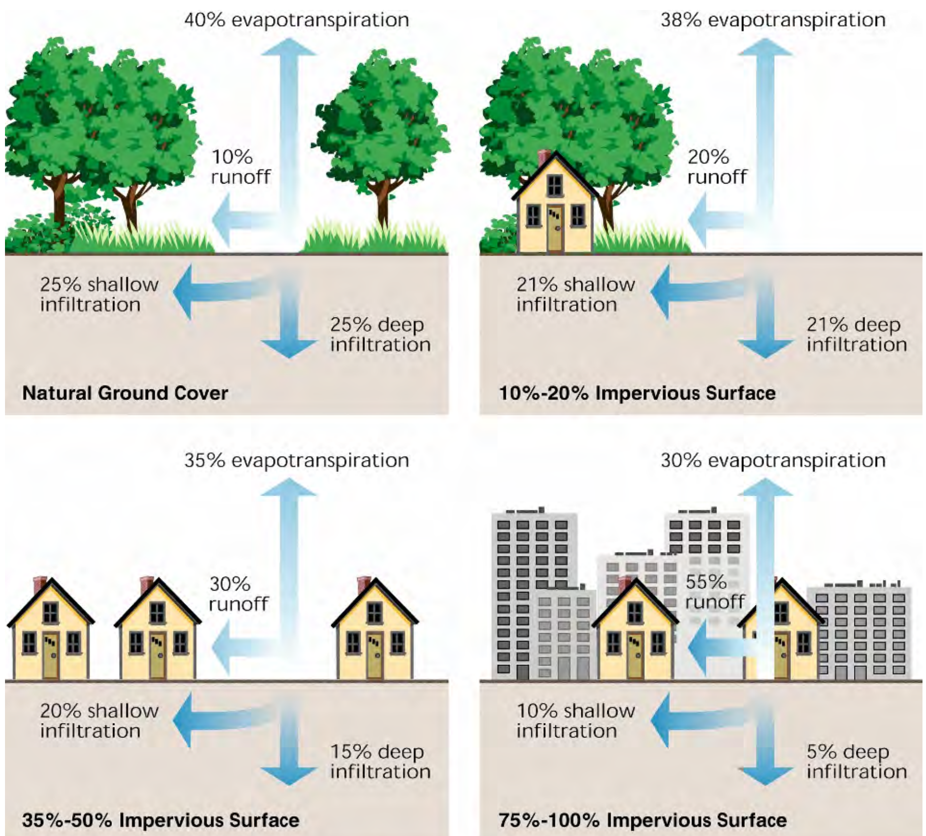

Fig. 3.21 -- Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

As more and more land is converted from **pervious surfaces** like woods and fields to **impervious surfaces** like as buildings, roads, and parking lots, less water soaks into the ground. This reduces **groundwater recharge** which can negatively impact drinking water supplies. Depleted groundwater reserves combined with drought can harm trees and cause surface water bodies to run dry. Water that cannot soak into the ground or transpire back into the atmosphere has to go *somewhere,* so it runs off the land. To prevent flooding of houses and roads, cities install **storm drain systems** that include a network of ditches and/or storm water pipes to convey surface water runoff from streets to streams and/or other water bodies. Unfortunately when runoff is diverted directly to streams, the pollutants are not filtered out like they are when the runoff percolates through soil into the ground. Water pollution from runoff is called **nonpoint source water pollution**.

Creating and maintaining storm drain systems is expensive and sometimes development outpaces creation of new infrastructure. When this happens, flash flooding can occur. **Flash flooding** is when water rises rapidly during and after storm events spilling out of the stream channel. It can cause homes, businesses, and roadways to become covered with water. Flooding also causes stream banks to erode and makes the streams wider. And because less water percolates in the ground to be stored, during periods of little to no rain, local streams can go dry. When streams go from extremes like flooding to drying out, it is very difficult to maintain healthy stable stream ecosystems that support aquatic life like game fish. Because storm sewer systems are expensive, cities have been exploring alternative low cost and easy to maintain ways to get runoff to soak back into the ground. One popular method is called "**rain gardens**."

Successful **rain gardens** are designed to capture and store runoff. **Runoff sources** include overland flow, diverted downspouts from roof tops, channeled flow, and water diverted from rain barrels. Regardless of the sources, it is very important to figure out how much runoff will reach the rain garden.

Experts differ on what percent of surface water runoff rain gardens should be designed to capture and what variables (soil type, slope, land use, etc.) need to be considered when calculating rain garden storage volumes. Several different methods are presented below. The various methods yield different results and no single method has been proven to be more effective thnt another to date.

Volume is calculated using depth and area and is expressed in cubic feet (ft^3). The goal is to develop a bowl shaped receptacle that will capture most the runoff during a typical rain event. To determine the right size of your rain garden, it is necessary to know how much water you are going to need to store in gallons and convert that to cubic feet. Soil porosity will determine the maximum depth of the garden. Based on volume and depth, it is possible to determine the rain garden area in square feet. Rain garden shape (length and width) can be determined by visually inspecting the location where the rain garden will be located. As a general rule it is better to make the garden larger than is needed to capture the runoff. You can convert all of the calculations to metric if you wish but English units are more commonly used in weather reporting and landscaping.

<u>Calculating Runoff Area</u>:
Runoff area is reported in square feet and is the drainage area that would contribute runoff to the rain garden. A rain garden can have one or more sources of water including surface water runoff, downspout runoff, and rain barrel water.

1) ***Downspout Method*:** Measure the foot print of the building in square feet (length x width looking from the top of the building) and then divide this number by the total number of downspouts will give you a good average. For example, if the school building is 240 feet x 160 feet, the area is 38,400 square feet. Assuming that there are 4 downspouts, divide 38,400 by 4 and you get 9,600 square feet of surface area draining to each downspout. Assuming one inch of average rainfall divide 9,600 square feet by 12 and you would get a volume of 800 cubic feet of water coming from each downspout.
2) ***Square-foot Area Method:*** Use the actual topographic map showing the drainage area and a Dot Grid (see Appendices for **Dot Grid Master**).to calculate the surface area in acres that drains to their proposed rain garden location. A **Dot Grid** is an acetate overlay you put over either a 1:24,000 or 1:100,000 topographic maps to determine acres. A Dot Grid is divided into a series of squares with 4 dots in each square. 16 squares make up 1 square inch and the lines around the inch squares are darker. To use the Dot Grid you count all of the dots and multiply that times acres per dot. For a 1:24,000 topographic map, you multiply the dots times 1.43. If the watershed is larger than the Dot Grid area, divide the area into smaller areas, count each area separately, and add the total dots before multiplying by the dots per acre factor. Then multiply acres time square feet to get the area using this formula: 1 acre = 43,560 square feet. Assuming one inch of average rainfall, divide the area by 12 to get cubic feet of surface water runoff.
3) ***Runoff Coefficients:*** To use runoff coefficients, you need use a topographic map of your site. Using the a key to topographic maps, identify the various land uses by color and measure their sizes using the Square

Foot area method with a Dot Grid. Then multiply the areas by the Storm Runoff Coefficient and add the sums together to determine how much surface water drainage will enter the rain garden.

Runoff Coefficients (Source: Indiana Geological Survey)

Land use - Description	**Color Code on topographic Map**	**Storm Runoff coefficient**
Open water	Blue	0.00
Residential	Pink	0.40
Urban	Red	0.70
Rock/sand/clay	Brown	0.80
Forests	Dark Green	0.15
Grasslands/shrubs	Yellow Green	0.25
Crops	Yellow	0.40
Recreational grasses	White	0.20
Wetlands	Olive Green	0.05

Calculating Depth

There are two methods to determine the right depth of your rain garden. A good rule of thumb is that the garden depth should never exceed 12 inches in clay-type soils and 18 inches in sandy soils.

1) ***Slope and Depth Calculation:*** To do this, use the **Slope Handout** in the Appendices. To determine the slope, set one stake at the highest point uphill of your proposed rain garden site. Then set another stake downhill at where you propose to have your rain garden. Connect the two stakes with a string making sure to keep the string level. ***The string on the uphill side should be flush with the ground.*** Depending on the slope you may need to use a taller stake or have a person hold the downhill string so it is level. Use a line level to make sure the string is level. Start out by measuring the height in inches between the grounds surface and the top of the string at the downhill stake. Next, measure the length of the string in inches. Slope equals the rise (height) divided by the run (length) so you will use the formula: H/L x 100 = %S where H is height, L is length, and %S is percent slope. The % slope is used to determine what depth the rain garden should be. When you have determined the slope, use the Slope Depth Chart for Rain Gardens below to determine your rain garden depth.

Slope Depth Chart for Rain Gardens

< 4 %	3-5 inches
5% - 7%	6-7 inches
8-12%	8 inches maximum

2) ***Infiltration or Perk Test method:*** To conduct a percolation test, make a round 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. Then 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 day. For example, it takes 4 hours for the water to drain one inch. To convert this measurement to inches used the following formula:

$$\frac{1 \text{ inch}}{4 \text{ hours}} \times \frac{24 \text{ hours}}{1 \text{ day}} = 6 \text{ inches per day}$$

Calculating Volume

Once depth is determined, you can determine the rain garden area. There are a variety of methods for calculating volume.

1) ***Rainfall Method:*** Select an amount of rainfall the garden needs to hold (one inch, two inches, etc.) and use the runoff area to calculate the rain garden volume. For example, if the drainage area of the school yard is 64 feet x 32 feet, the area is 2048 square feet. If the goal is to capture 1 inch of rainfall, divide 2048 square feet by 12 to get a rain garden area of approximately 170 square feet.

2) ***Soil Type Method:*** Using this method, different soil coefficients can be used. Multiply the soil type coefficient for your specific rain garden by the runoff area. A different table is used depending on whether the garden is

greater or less than 30 feet from downspout source. Soil Coefficient by Depth tables are below. These tables assume the slope method has been used to calculate the garden depth.

Soil Coefficients by Depth - < 30 Feet from Downspout

	4 inches	6 inches	8 inches
Sandy soil	0.19	0.15	0.08
Silty Soil	1.35	0.25	0.06
Clayey Soil	0.43	0.32	0.20

Soil Coefficients by Depth - >30 Feet From Downspout

	4 inches	6 inches	8 inches
Sandy soil	0.03	0.03	0.03
Silty Soil	.06	0.06	0.06
Clayey Soil	0.10	0.10	0.1

For example, is you have heavy clay soils, the rain garden is located over 30 feet from the downspout, and you have determined that you need a 6 inch deep rain garden, you would multiply your runoff area or 2048 square feet by a coefficient of 0.32 to get a rain garden area of approximately 655 square feet.

3) ***Ratio Method:*** This variation of the soil type method uses proportions or ratios. For example, if the soil is a sandy soil, the proportion is 5:1 with 5 being the rain volume and 1 being the garden size. Essentially the garden would be designed to hold one fifth of the runoff volume. Sandy loams use a 4:1, Silty loams us a 3:1, and clayey soils use 2:1 ratios. Assuming clay soils, a rain garden depth of 6 inches, and a runoff area of 2048 square feet, calculate the area by multiplying 2048 by 0.5 feet and divide the result by 2 for the clay soil ratio. The result would be an approximately 512 square foot rain garden area.

<u>Selecting Length and Width:</u>
Selecting length and width is a matter of visiting the site and determining what space is available. The garden should be oriented so the water comes in perpendicular to the widest part of the garden ideally. Most rain gardens are oval or kidney bean shaped. If the area of the rain garden is 512 square feet and the site is a square area that is 25 x 30 feet (750 square feet), one possible size of the rain garden is approximately 18.5 x 28 feet.

Lesson Descriptions:

Option 1: Elementary School

Objectives: Students will:

1) Experiment with different shaped containers that hold the same volume of water to determine which might work best for a rain garden;"
2) Make a simple map of the school yard and use it to create a 3-dimensional model of the school,
3) Have the students experiment to see which shapes, orientations, and slopes of a rain garden captures and stores water best.
4) Calculate the volume of water that runs off your school site.
5) Install a rain gauge at the school and use rainfall data and the area from your simple schoolyard map to calculate the amount of water that will runoff in a single storm event.

Topics Covered: Area, Volume, Dependent and Independant Variables, Precipitation, Weather, Topographic Maps, Pervious/ Impervious surfaces, Problem Solving, Experimental Design

Activity Time:
1 class period

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

Materials:
Paper
Pencils with erasers
Clip board
Rain gauge
Measuring tape
Graph paper
Colored paper (optional)
9 x 13 x 2 inch container
Sand
Plastic wrap
Measuring cup
Water
Sponges

Follow Up:
Same as Hands On
Paper towels

Extension:
National Weather Service Data for School Site
Calculator

Introduction: Lead a discussion that picks up on the discussion from the lesson ***No Place to Run*** where students experimented with ways to get water to soak into the ground. Assume a rain garden will be planted on the school site to capture the runoff. Take a walk around the school grounds to decide where to put one. A good place is where most of the runoff can roll down hill and get captured in the garden or where the downspout can be disconnected to supply water to the rain garden. Make a map of the school site showing where they propose to put the rain garden including site measurements and arrows showing the water flow. How would they determine what size to make the garden? What other factors might influence the size and shape of a rain garden? They are going to experiment with shape, orientation and slopes to see how these factors influence rain garden design and placement.

Hands On:

1) Students are going to design an experiment to test different shapes, orientations, and slopes to capture runoff works best for a rain gardens. How would they design their experiments? Make a list of variables. Which need to be controlled and which are the independent variables?
    a) To test the shapes of the rain gardens, what variable(s) need to be controlled? (size of sponges, orientation, amount of water, slope, and amount of time the water is allowed to runoff the model must be the same.)
    b) To test the orientation of the rain gardens, what variable(s) need to be controlled? (size of sponges, shape of the sponges, amount of water, slope, and the amount of time the water is allowed to runoff the model must be the same.)
    c) To test the slope of the rain gardens, what variable(s) need to be controlled? (the shape, orientation, the amount of water, and the amount of time the water is allowed to runoff the model must be the same.)
    d) Have students develop a written study plan before they conduct the experiment.

2) Conduct the experiments.
   a) Divide the class into teams of 3-4 students.
   b) Give each team a container filled with sand, a roll of plastic wrap, dry sponges, measuring cup, paper towels, and scissors (optional – if they are cutting out shapes).
   c) Have students conduct the shape experiment first.
      i) The shapes can be pre-cut or you can have the students cut the shapes. Make sure the sponge area is the same for each shape. Assign each team a shape: circle, square/rectangle, oval, triangle, etc. Have them cover the sand with the plastic wrap and use their fingers to create a depression to hold their shape. For this experiment the sponge should be flat. Make sure they do not puncture the plastic wrap, Make sure the sponge is level with the top of the sand/plastic wrap.
      ii) It works best if the teacher is the "water keeper." The teacher needs a small sprinkling can, cup measure, and water.
      iii) Orient the pan so the longest side is used for tilting the pan. Put a ½ inch deep book or object under the top of the model. Place the rain garden 1/3 of the distance from the bottom of the pan.
      iv) Sprinkle ½ cup of water on the upper edge of the model. Time the runoff for 1 minute. Pull out the sponge and wring it out in the measuring cup. Record the amount on a class chart.
      v) Repeat watering until all shape models are completed. Which shape captured the most runoff? Why?
   d) Conduct the orientation experiment:
      i) Use paper towels to dry off the plastic wrap and give the teams a dry sponge for the next experiment. All students will get the same size and shape sponge.
      ii) Have the students orient the sponge in different ways to the water source. Make some perpendicular, some parallel, and some at other angles to the water source.
      iii) Repeat the experiment with the same amount of water and record results. Which orientation worked best?
   e) Conduct the slope experiment:
      i) Use paper towels to dry off the plastic wrap and give the teams a dry sponge for the next experiment. All students will get the same size and shape sponge.
      ii) Change the slopes of the containers. Make some flat, some ½ inch, some 1 inch, and some 2 inches.
      iii) Repeat the experiment with the same amount of water and record results. Which orientation worked best?
   f) When the class chart is completed, discuss the results. Which shapes worked best and why? Did orientation matter? How? Which orientation worked best and why? Did slope matter? Why? When rain gardens are built on a slope, they cut and fill the area so the rain garden is flat and there is a berm at the down slope side. Why do they do that? Can you simulate that with your models? How? What did you learn today that will help you choose the location, size, and shape of the school rain garden?

Follow-up: Ask students to think about how they could repeat this experiment to approximate the conditions on their school site? Have them redesign the experiment so it is proportional to conditions on their school site and test rain garden shapes, sizes, and orientation.

Extensions:

1) Use local rainfall data obtained from weather reports or the National Weather Service to determine what the average rainfall is for your area. Have the students install a rain gauge in the proposed location of their rain garden site and monitor rain fall. Check the local weather reports to determine how close their data is to the data the weatherperson reports.
2) Use the runoff area from their school and average rainfall data to calculate the volume of water their rain garden needs to hold. Use the **Calculating Runoff Worksheet** in the Appendices. If the school building is 240 feet x 160 feet, the area is 38,400 square feet. Assuming that there are 4 downspouts, divide 38,400 by 4 to get 9,600 square feet per downspout. Assuming one inch of average rainfall divide 9,600 square feet by 12 and you would get a volume of 800 cubic feet of water coming from each downspout. Then convert cubic feet to gallons using this formula: 1 cubic foot = 7.48 gallons of water. Converted to gallons, 800 cubic feet is 5,984 gallons. To put this into perspective, have the students determine how many 5 minute showers it would take to equal the runoff from this section of the roof. An average 5 minute shower uses 25 gallons of water divided by 5,984 gallons is about 240 showers!

Option 2: Middle School

Objectives: Students will:

1) Use the topographic map showing the drainage area of the schoolyard (or watershed boundary of the school) and the proposed location of the rain garden from the ***No Place to Run To*** lesson to calculate the surface area draining to the rain garden;
2) Used the drainage area from your schoolyard and local weather data to calculate the maximum volume of water the rain garden will need to store; and
3) Calculate the slope of the schools rain garden site and select runoff co-efficient that related to percent slope; and
4) Determine the size and shape of a rain garden that would work best for your site.

Topics Covered: Area, Volume, Precipitation, Weather, Topographic Maps, Pervious/ Impervious surfaces, Problem Solving, Experimental Design

Activity Time:

1-2 class periods

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

Materials:

Paper
Pencils with erasers
Clip Board
Calculators
7.5 minute topographic map of school site
Acetate copy of Dot Grid
Dry erase markers
Stakes
String
Line Level
Measuring Tape

Follow Up:

None

Extension

None

Introduction:

Lead a discussion that picks up on the discussion from the ***No Place to Run To*** lesson, What factors would students need to consider to make sure the rain garden they design is the right size? (runoff volume, depth that will still support plant life, garden that will drain of water in 24 hours, garden that fits the size and shape of the site available). The first step is to calculate the amount of runoff. How would they do that? (size of area draining to garden, size and duration of storm events). They will use the watershed boundary maps of their proposed rain garden site to calculate the volume of runoff in cubic feet. Then they will conduct research to determine rainfall patterns. What type of rain fall information would be valuable? (average rainfall, maximum amounts of rain in a single event, times of year when the ground is saturated because of rain events in rapid succession, etc.) The garden needs to be designed to accommodate an average rainfall event and have an outfall so that if it rains more than that, the garden has a safe place to overflow. If you are designing a rain garden for heavy clay soils, it needs to hold approximately 35%- 50% of the runoff from one rain event. One of the more important decisions students will have to make it the depth of the rain garden. Rain gardens can be between 6 – 18 inches deep depending on soil conditions and slope. Ask why they think slope is important? (Water runs faster down steeper slopes and does not soak in so you need a deeper bowl to hold it.) Ask why they think soil type is a factor? (Some soils are more porous than others and it is important the garden drains in 24-48 hours to keep the plants alive and prevent the garden from breeding mosquitoes!). To calculate the rain garden depth for this activity, they calculate the slope of the site. The depth of the garden and the actual site where they plan to put the garden will dictate the length and width of their garden. During this activity the students will actually determine the size of their garden.

Hands On:

1) Calculating Runoff Area: Students will determine the source of water for their rain garden and measure this area. If the water source is from one or more downspout they will use the Downspout Method. If the source of their runoff is overland flow, they will use Square-foot Area Method. In some cases, the methods may need to be combined and the results added together. Use the handout called **Sizing a Rain Garden – Middle School** student worksheet in the Appendix to record results and assist with the calculations. See the

Background Section in this activity for the Downspout and Square Foot calculation methods. Use 1) the actual topographic map showing the drainage area of the schoolyard (or watershed boundary of the school); 2) the proposed location of the rain garden from the ***No Place to Run To*** Middle School lesson; and 3) a Dot Grid (see appendix for Dot Grid Master) to calculate the surface area in acres that drains to their proposed rain garden location. (NOTE: If you have blown up your map, you can blow up the dot grid by the same exact proportion and use it without changing the calculations).

2) **Determining Rain Garden Depth from Slope:** Students will determine the slope of the land that leads to their rain garden site. Remind them the greater the slope, the more difficult it is for water to soak into the ground so you need a deeper rain garden. This is important to consider when designing a rain garden. Follow the *Slope and Depth Calculation* method in the Background section of this activity.

3) **Calculating Total Volume of Runoff Using Slope:** Take the area and multiply it times the slope depth in using the chart in the Background Section of this activity. For example, if you are using the downspout area method above and the school was 32 feet x 96 feet with 4 downspouts, the runoff area for one downspout would be ¼ of that or 768 square feet. If the slope from the downspout to the rain garden is 6% or less, you would multiply the size of the drainage area - 768 square feet by the depth of the rain garden or 0.5 feet (6 inches divided by 12) to get a rain garden volume of 384 cubic feet.

4) **Calculating the Dimension of Your Rain Garden using Ratio Method:** Assuming the rain garden will be planted in heavy clay soil, you would use a 2:1 or 3:1 ratio. For a 2:1 ratio, the rain garden would need to be ½ the size of the runoff area or 384 feet divided by 2 or 192 cubic feet. Assuming that the garden is 6 inches deep, divide 192 by 0.5 to get the square feet dimension of the garden. The total area of the garden would be 384 square feet.

5) **Garden Orientation:** Depending upon the area available and how you want to orient the garden, the garden could have any number of dimensions. In general you want to orient the garden perpendicular to the water source in an oval or rectangular shape where the length is greater than the width.

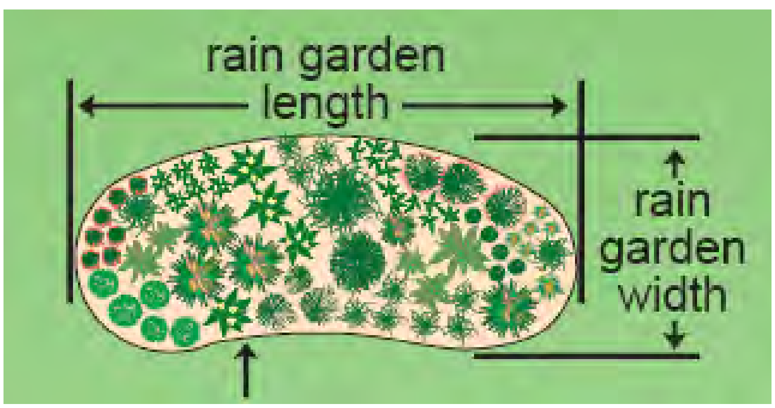

Illustration Source: Rain Gardens A How to Manual for Homeowners, UW-Extension offices, Cooperative Extension Publications, University of Wisconsin, 2003.

In this example, if the length was approximately 25 feet, the width would be approximately 15 feet assuming a rain garden depth of 0.5 feet or 6 inches.

Follow-up: Have students test different rain garden shapes, orientation, and slopes following the directions ***Capture, Store, and Release*** Option 1: Elementary school of the Hands On portion of the lesson.

Extension: Have an engineer examine the work the students have done and see if they agree with the students' calculations and garden shape.

Option 3: High School

Objectives: Students will:

1) Use a topographic map showing the drainage area of the schoolyard (or watershed boundary of the school) and the proposed location of the rain garden from the ***No Place to Run To*** lesson to calculate the surface area draining to the rain garden;
2) Use the drainage area from your schoolyard and local weather data to calculate the maximum volume of water the rain garden will need to store;
3) Distinguish between pervious and impervious areas in the watershed and use drainage co-efficients to more accurately predict runoff volumes. Then use the formula provided to determine the actual size of the rain garden needed for your school;
4) Calculate the slope of the schools rain garden site and select runoff co-efficient that related to percent slope; and
5) Determine the size and shape of a rain garden that would work best for your site.

Topics Covered: Area, Volume, Precipitation, Weather, Topographic Maps, Pervious and Impervious surfaces, Problem Solving, Experimental Design

Activity Time:
1-3 class periods

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

Materials:
Paper
Pencils with erasers
Clip Board
Calculators
7.5 minute topographic map of school site
Acetate copy of Dot Grid
Dry erase markers
Stakes
String
Measuring Tape
Line Level
Runoff Coefficient Chart
Rain gauge
National Weather Service Data for School

Follow Up:
None

Extension
None

Introduction:
Lead a discussion that picks up on the discussion from the ***No Place to Run*** Middle School Introduction. High School Students will use the Watershed maps generated in the ***No Place to Run*** lesson to estimate the volume of runoff that could drain to their rain garden. In addition to calculating the runoff area, students will use runoff coefficients for specific land covers to more precisely calculate runoff volumes. They will also calculate slope and use all of their information to determine the size and shape of their proposed rain garden.

Optional: If you wish, you can use Online Watershed Delineation (OWL) Tools instead to calculate the watershed area draining into a point that you have selected on an interactive map from the College of Engineering at Purdue University. The program is called L-THIA 2.0 Watershed Delineation and Runoff Analysis. You have to have your longitude/ latitude coordinates to use this site. It is available for the 6 states in EPA Region 5 (Indiana, Illinois, Wisconsin, Minnesota, Michigan, Ohio). Once you have determined your watershed using the watershed delineator tool you can estimate impervious area of your watershed (run L-THIA),or download the data to your computer (http://cobweb.ecn.purdue.edu/mapserve/www/lthia_in/index.html). There is a powerpoint presentation on the website called "Web-based GIS for Hydrological Analysis" by Bernie Nagel and Larry Theller that explains how to use L-THIA. It can be found at: http://engineering.purdue.edu/.../Hydrologic_Impacet_Analysis_woth_LTHIA_MODEL.pptx. For more information about GIS Tools for Watershed Management, visit: Http://www.extension.purdue.edu/waterqualityGIS.htm.

Hands On:

1) Revisit the school site and use the watershed map created in ***No Place to Run*** to color code the land use type on their maps using colored markers or pencils. Use the colors indicated in the Runoff Coefficients included (see Appendix for Student Hand Out of this chart.)

Runoff Coefficients (Source: Indiana Geological Survey)

Land use - Description	**Color Code for Map**	**Storm Runoff coefficient**
Open water	Blue	0.00
Residential	Pink	0.40
Urban	Red	0.70
Rock/sand/clay	Brown	0.80
Forests	Dark Green	0.15
Grasslands/shrubs	Yellow Green	0.25
Crops	Yellow	0.40
Recreational grasses	White	0.20
Wetlands	Olive Green	0.05

2) Use the color coded topographic map and a Dot Grid to calculate the area of each type of land use separately (see Appendix for Dot Grid Master with instructions.) Note: If the topographic map was enlarged to 400%, enlarge the Dot Grid Acetate Overlay to 400%. Then convert acres to square feet and multiple the areas times the Runoff Coefficients. Add each land use type together and use this for the area.

3) Research actual rainfall records for your area to determine the average rainfall intensity over a 24 hour period. Use local weather data or data from the National Weather Service. Pick out several storm events of various sizes (1/2 inch in 24 hours, 1 inch in 24 hours, 2 inches in 24 hours, etc.) and average the amount of rain that falls per hour during the storm. This information will be used to calculate runoff in the next step. If there is a rain gauge at your school, use data from this gauge to determine average hourly rain fall.

4) Now have the students calculate the average amount of runoff from *each land use type* their school sites using a formula that estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and average rainfall for duration equal to one day. The formula is expressed as follows:

$$R = CAI$$

R = Rain Garden size (cubic feet)
C = runoff coefficient representing a ratio of runoff to rainfall
A = drainage area contributing to the rain garden location from Dot Grid (convert acres to feet)
I = average rainfall (inches/day expressed in feet)

Note:* Make sure the students convert the units so the final answer is in cfs. This is the average rate of runoff to your rain garden. Use the **Sizing A Rain Garden – High School student worksheet located in the Appendices to aid with performing the calculations.

5) Have the students complete ***Capture Store and Release*** Middle School Option Hands On Steps 2-5.

Follow-ups:

1) Repeat this lesson using the maximum amount of rain fall that occurred on a day to perform the calculations. How much larger would the rain garden have to be to accommodate the maximum rainfall? Is that practical? Why or why not? Why to professionals design rain gardens to hold an average of 1 inch per day of rainfall?
2) What are the various sizes and shapes possible for a Rain Garden to hold the average amount of rainfall as determined on the student worksheet? Which would work best and why? What factors need to be considered? (plants do not sit in standing water for more than 24 hours; water spreads out evenly to drain faster, ability to trap runoff effectively, space available at the school, esthetics, and others). Divide into teams and decide on the perfect size and shape and draw the proposed rain garden on the site map. Have the

teams share their ideas with the rest of the class and then evaluate each proposal. Which design would work best and why?

Extension: Invite a Civil Engineer to visit the class and work with the students to calculate the average amount of runoff a rain garden in the location they selected would receive or invite a Civil Engineer to visit the class to evaluate the proposal rain garden location, shape, and size.