Rain Garden Lesson Guide

Clermont Soil and Water Conservation District
OEEF General Grant F-09G-018

December 2009

This project was funded by the Ohio Environmental Protection Agency though a General Grant to Clermont County Soil & Water Conservation District called ***Partnering to Protect Water Resources: A Rain Garden Demonstration and Education Project*** OEEF General Grant F-09G-018

Education Team:
Anne Lyon, Director, Greenacres Water Quality Project LLC
Meri Johnson, Science Curriculum Consultant, Clermont County Educational Service Center
Judy Krebs, Education Specialist, Clermont County Soil and Water Conservation District

Participating Schools and Teachers:
Batavia High School: Emily Hicks and Bob Walker
Bethel Tate Local Middle School: Susan Dotson and Sandy Hastings
Clermont Northeastern High School: Tony Gettler, Lauren Lu, and Jill Stegeman
Clough Pike Elementary School: Beth Testa
Felicity-Franklin High School: Catherine Howes and Guy Hopkins
Goshen Local High School: Davey Brown
Grant Career Center: Gary Broadwell and Nancy Weis
Milford Junior High School: Rachelle Rapp-Dickerson
Pattison Elementary School: Kate Clarisey
Williamsburg Middle School: Barb Doppes and Layla Gregory

Project Team:
Paul Berringer, District Administrator, Clermont Soil & Water Conservation District
John McManus, Program Manager, Clermont County Water Resources Department - Storm Water Management Division
Anne Lyon, Director, Greenacres Water Quality Project LLC
Meri Johnson, Science Curriculum Consultant Clermont County Educational Service Center
Wes Duren, Landscape/ Construction VP, Marvin's Organic Gardens

TABLE OF CONTENTS

APPENDICES:

Lesson 1: No Place to Run

Lesson Overview:

Purposes: To help students understand:

1) why storm water runoff can be a problem and
2) how rain gardens can be used to help manage storm water.

Background:

Urban areas in America are experiencing unprecedented growth. And with growth comes the need for storm water management. As more and more land is developed, there is no place for water to soak in so larger volumes of runoff are traveling through storm drains untreated to streams instead. Given this challenge, Storm Water Managers are "thinking out of the box" and using more low cost "green" alternatives to manage storm water like rain gardens and rain barrels. **Rain gardens** are shallow depressions that are designed to intercept and capture surface water runoff or water from downspouts. They resemble perennial garden beds. Runoff trapped in the rain garden is absorbed by the soil where pollutants are removed before the water is taken up by plants and released back into the atmosphere. Rain gardens can be an attractive focal point in the landscape and serve as wildlife habitat. **Rain barrels** are containers used to intercept rainfall from runoff and/or downspouts and store it for other uses like watering lawns and gardens. Rain barrels and rain gardens can also be used in combination. For example, downspouts can be diverted to rain barrels and the water from the rain barrel can be used to water the rain garden. Rain gardens can serve as an exciting outdoor learning laboratory where students use their skills and knowledge to solve a real-world problem – storm water management. In addition to monitoring how effective the rain garden is in capturing and purifying runoff, they can be used for years to come for students to study soils, porosity, water quality, plants, wildlife, ecosystems, and succession.

To understand how rain gardens work, it is necessary to become familiar with the way **water "cycles"** in natural environments. Rain falls onto the lands surface where it soaks into the ground and becomes part of groundwater, or it runs off into a stream, pond, lake, wetlands or ocean. Plants slow the velocity of the rain and help the soil absorb the water. The water that we can see is called **surface water**. Water that flows over the surface of land is called **runoff.** Most runoff comes from rain and snow. The spaces between soil and rocks that store water underground are called **aquifers** and they store **groundwater**. The top surface of ground water is called the **water table**. The height of streams, ponds, lakes, wetlands, and oceans is the top of the water table. Ground water flows slowly downhill through soil where many of the impurities are filtered out until it percolates into streams, ponds, lakes, and even the ocean. The process of precipitation soaking into the ground and becoming part of the aquifer is called **groundwater recharge**. Groundwater is the **base flow** that keeps water bodies filled with water during dry periods. During wet periods, base flow and surface water runoff combine to fill water bodies and the water level in the stream is higher. Depending on the amount of rain, the stream can escape its channel and overflow onto the floodplain; this is called **flooding**.

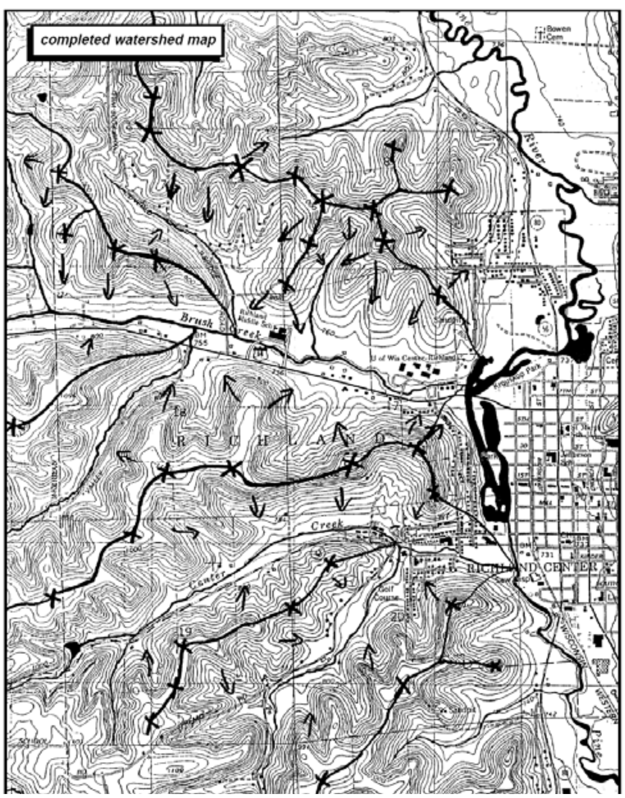
Gravity causes water to run from the highest point to the lowest point. The shape and composition of the earth determines how and where water will flow. Some of the earth's surface is more **porous or pervious** than others. For example, black top, pavement, and buildings are not porous or **impervious** so water runs off these surfaces. Other surfaces like grass, woodlands, croplands, forests, and wetlands are more porous or **pervious** and allow different amounts of water to soak into them. The slope of the earth surface also affects how much water can be absorbed. In general, the more gentle the slope, the greater the chance water will soak into pervious surfaces. As the slope increases, more and more water will runoff the land before soaking in. Weather also plays a factor. For example, the heavier the rain, the more water will run off the land rather than soaking in. Whether or not the ground is still saturated from a previous rain also affects porosity. As more and more land is developed, there are less porous areas for precipitation to soak into.

It is possible to actually predict how much water will run off land after a rain event. A calculation can be performed using watershed size (drainage area), soil porosity, runoff coefficients for different land uses, and rainfall. Topographic maps are used to measure drainage areas and local weather information can be used to determine rainfall. The drainage area and amount of rainfall in inches can be used to determine the volume of water that contributes runoff to a particular water body.

Special maps called **topographic maps** are used to represent the earths' 3-dimensional shape in 2-dimensions. A topographic quadrangle map is one 7.5 x 7.5 minute rectangle of the earth's surface that has been created from aerial photographs to show features on the earth's surface. **Cartographers** or map makers divide the earth into squares by horizontal and vertical lines. The vertical lines or **Meridians of Longitude** are north-south lines connecting the poles and the horizontal lines are **Parallels of Latitude** are east-west lines parallel to the equator. Meridians and Parallels are circles that have 360 degrees, 60 minutes per degree, and 60 seconds per minute. There are 3,600 seconds per degree. Locations on the earth are expressed as degrees, minutes and seconds. For example, 39° 8' 8.5" is equal to 39 degrees, 8 minutes, 8.5 seconds latitude. To describe a location on the earth the longitude and latitude coordinates are needed. For example, Avey's Run at Cincinnati Nature Center is 39° 7' 56.3" latitude and 84° 15' 21.9" longitude.

Contour lines represent the lands elevation about sea level. Contour lines run parallel and the connect points at the same elevation. The interval or distance between 2 topographic lines is usually 10 or 20 feet. Every fifth brown parallel line is a heavier brown line with a number in it; this is the elevation above sea level. Topographic maps use colors to represent different features. Contour lines are brown. Woodland and wetlands are green. Black features are building and roads. Pink features are urban areas. Yellow areas are mines and the red areas are landfills. Purple features are items that have been added to the map since the last edition of the maps and have not been verified.

Topographic maps can be used to determine the direction water is flowing. The land area that contributes runoff to a specific point or place is called a **watershed.** The watershed for a school yard is the land area that contributes water to the lowest point on the school grounds. The watershed of the Little Miami River is the land area (including tributaries) that drains to where the Little Miami River meets the Ohio River. Watersheds can vary in size depending on the reference point. For example, the watershed of the Little Miami River is much larger than the watershed of one of the tributary streams like O'Bannon Creek that feeds into it. A watershed is also a geographic community that includes all living and non-living things such as humans, animals, plants, soil, rocks,



Source: Give Water A Hand

Lesson Descriptions:

Option 1: Upper Elementary (Grades 3-5):

Objectives: Students will:

1) Distinguish a pervious from impervious surfaces;
2) Trace the path of water from precipitation to runoff and storage; and
3) Construct a model to demonstrate how changes in percent impervious surfaces help manage storm water runoff.

Topics Covered: Water Cycle, Pervious and Impervious Surfaces, Weather, Precipitation, Flooding, Groundwater Recharge, Land Use, and Water Pollution

Activity Time: 1 class period

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

Materials:
Sidewalk chalk or ball of string and tent stakes
9 x 13 x 2 inch container with a hole drilled in either one corner or the middle of one side at the top edge of the container
Modeling Clay (4 or 5 pound block) or other modeling clay
Dental floss for cutting clay layers from block
Rolling pins or 16 oz food cans (full cans)
Sponges or other porous material like pillow foam
Plastic spoon
Scissors or X-acto knife
Plastic table knives
Small garden watering can
Source of Water
Plastic cup to catch water from hole in plastic container
2 cup measuring cup or beaker
Set of crayons
Notebook paper
Pencils
Sand

Follow Up:
Same as Hands On

Extension:
Plastic straws
Food coloring
Powered drink mixes

Introduction

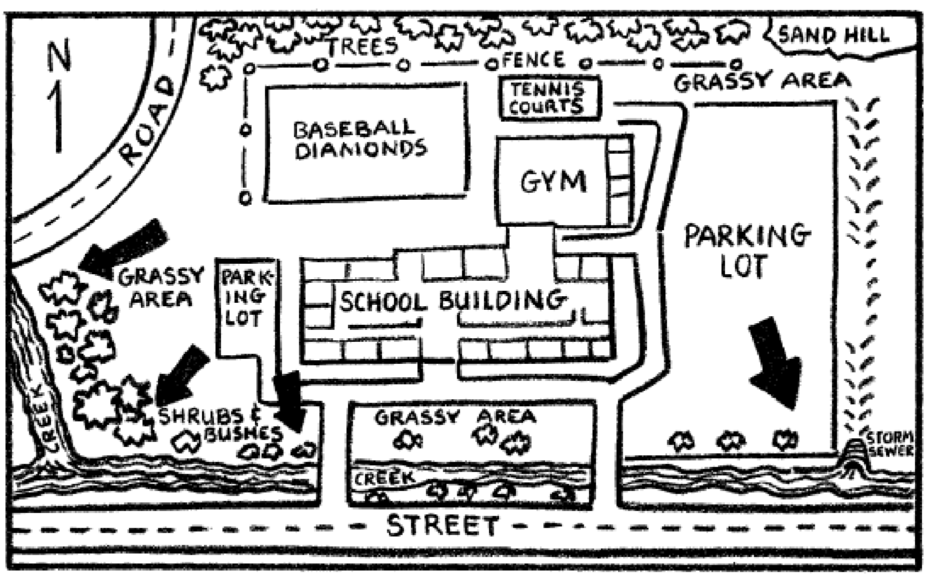
Begin inquiry with a discussion of "where does water go when it rains?" Discuss how water runs off the land. Answers will vary, but should include that rain soaks into the ground, runs over the land to a water body, runs down the roads into storm drains, etc. What happens to the water that falls on a home or the school? If the students were a water drop that landed at the school, where would they go? Would they soak into the ground? If so, the ground is porous or pervious to water. Would they soak in if they landed on the parking lot? If they cannot soak in the ground is impervious. Where would they go if they could not soak into the ground? They move downhill by gravity to a place where they can soak in. Discuss how gutters capture the water and direct it to the street where it flows into storm drains that run into the river. What happens when we have a particularly heavy rain? Discuss how some streams and rivers overflow or **flood**. Think about reasons that water flows over the ground instead of soaking into the ground. Discuss how some surfaces are **pervious** and some are **impervious.** Mention that even some pervious surfaces can become impervious under certain conditions like when the ground becomes saturated with rain and cannot absorb more water. Think of ways to get more water to soak into the ground. How they would make it easier for water to soak in or make the lands surface more pervious. Think about the school site. Are there ways to make it easier for water to soak into the ground on the school site? Discuss what a rain garden is and how it is used to capture and store water. Emphasize that a **rain garden** is a bowl-shaped garden placed down hill from where most runoff flows that is used to capture and store water. Plants help get the water to soak into the ground by breaking up the soil with their roots or they absorb the water and transpire it back into the atmosphere. The class is going to re-create their school site as a model to show how rain gardens work. The problem is: "What location on the school grounds is the most effective site for a rain garden?" Students are going to figure out where to put a rain garden to capture the most runoff and what size it should be to get the most water to soak into the ground.

Advanced Preparation:

1) Mark off the watershed area with sidewalk chalk or use stakes and string so the area is ready for the students to sketch.
2) Decide in advance how you want to orient your pan depending on the school site and have the hole drilled as close as you can to the top lip of the pan either in the middle or corner of the pan.
3) If you are using a block of clay, use dental floss to cut the layers and put plastic wrap between them so they are ready to pass out.

Hands On:

1) Divide the students into teams of 4-students and give each team a piece of paper, clip board, a set of crayons, two lids or containers with a hole drilled in center or corner of one the sides, a sheet of modeling clay, rolling pin or food can, clean dry sand, sponges or foam pieces, scissors, a plastic knife, an X-acto knife (optional), and a cup to catch the water.
2) Have teams:
   a) Cut a piece of paper the about ½ smaller than the size of their lid or container
   b) Make a layer of dry sand in each of the lid or container about 1 inch deep so that it is deeper than the sponges you are using.
   c) Place a sheet of plastic wrap on the table, put the clay layer on it, and use a rolling pin to make a layer of clay about ¼ inch thick to just a little bigger than the size of their paper. Tell students that the clay layer represents the impervious surface created when they built the school and made the parking lot, play ground, and driveways.
3) Place a sheet of paper on the clip board and have the students take it and their crayons outside to make a drawing of the school site.



Source: Give Water A Hand

4) Observe the area and note where the water will go when it rains. Ask where a good location would be to put a rain garden? The chalk or string represents the boundaries of the watershed. Students are going to draw the boundary first, and then sketch in all of the other elements like side walks, buildings, parking lot, and other features. Label each part of the drawing with a "P" is they think the area is porous or pervious. Label each part of the drawing with a "NP" or nonporous if it is an impervious surface like a parking lot. Look to see where water would flow on the site and to draw arrows indicating the direction of flow. Think about where they would place a rain garden but do not sketch it on the drawing. When the students have finished, return to the classroom.

5) Lay their drawing on top on the clay and use a rolling pin to merge the paper with the clay. For more accuracy, orient their drawing so the downhill side is next to the side with the drain hole.
6) Cut the clay piece the drawing so it is the size of the paper with a plastic knife or X-acto knife. Locate any areas in the drawing where the land is pervious (labeled “P”) and use scissors or an X-acto knife to cut it out (clay and paper layers). The sand should be exposed. Remove the clay pieces, peel away the paper, and save this clay for another purpose.
7) Carefully lay the clay layer onto the sand and use fingers to push the outside edges so they merge with the container so water cannot run into the sand around the outside edges.
8) In order for water to flow towards the hole, tilt the model by placing the “hole” side on the edge of table and the opposite side on a higher surface such as a book about ½ inch thick. Have one of the students hold a container under the hole to catch the runoff.
9) The activity works best if the teacher is the “water keeper.” Measure 1/2 cup of water and pour it into their sprinkling can. Gently pour the water onto the entire school site model using the sprinkling can. When all of the water has run off into the container, have a student pour the water into the measuring cup and record how much water ran off the model.
10) Using the data collected, write a description of the results and make an inference to the reason for the results.
11) Pose the following questions: Where would the best location for a rain garden on the model? Think about the school site. What would be the best shape? How large will the rain garden need to be in order to capture the most runoff? Now have the students think about where they might put a rain garden, what shape it should be, and how big it should be to capture the most amount of the runoff.
12) Gently remove the clay layer from the first lid or container and move it to the second dry container. Use fingers to push the outside edges so they merge with the container. Set the wet sand container aside.
13) Cut up a dry sponge in the shape they want the rain garden to be. Examine the sponge before the experiment. Use a spoon to excavate the sand from the selected location and place the sponge in area where the rain garden is planned. Make sure the sponge is level with the sand layer.
14) Repeat the experiment using ½ cup of water and recording how much water poured out.
15) Discuss what happened? Did the “rain garden” reduce the runoff amount?
16) Remove the sponge and examine it after the experiment? Ask them to explain what happened to the sponge and relate that to what happens in a rain garden.

Follow-ups:

1) Combine all the student data into one classroom table. Display the models on one table so everyone can look at them.
2) Lead a discussion. Did adding the rain garden significantly reduce the amount of water running off the property? Which teams model reduced the runoff the most and why? If given a chance to repeat the experiment, would they put their garden in a different place and why? How did the size of the garden affect how much water was removed?

Extensions:

1) Repeat the experiment using the saturated model and see how much of water was retained. Essentially this is what is happening in the spring after snow melts or when we have back-to-back storms. Discuss how you would use this information to design your rain garden. Explain that you might make the garden (sponge) bigger or you might install a drain (straw) so the garden drains to a storm drain and does not flood. Or use a different volume of water to simulate what happens in different size rain events such as 1/4 inch (1/8 cup), 1/2 inch (1/4 cups), 1 inch (1/2 cup) 2 inches (1 cup), and more.
2) Demonstrate what happens when water runs off the roof using your container. Using a bendable straw, put a straw through the clay layer of the model bend it so it is running parallel under the clay. This is the gutter. Attach the bendable straw to another straw and use masking tape to seal them. The straw running beneath the clay is the storm drain. Connect more straws until the line runs directly to the hole. Push the straw through the hole in the lid or container. The hole coming out the lid or container is the storm drain that would exit to the stream. Ask students if they ever saw a big concrete pipe that empties into a stream. Have they observed the storm drain outlet after a rain? What happens? Storm water running off impervious surfaces is traveling untreated to streams. Pour 1/2 cups of water into the container and let it run off. Note that over 98% of the roof runoff went into the container or would runoff into a storm drain. Some rain gardens are designed to capture roof runoff. The gutter is disconnected and redirected so the runoff flows into the rain garden. To demonstrate this, remove the straw from the hole and direct the straw into the rain garden (sponge) and pour water into it. Roof runoff can be captured roof in a rain barrel and directed into a rain garden or used for watering lawns and gardens. Show students pictures of rain garden where the gutter is directed into the garden and homes where rain barrels are attached to the downspouts and/or directed into rain gardens.
3) Use food coloring or drink mixes to simulate pollution that may be occurring on the school parking lot before you site your rain garden. Use green to represent fertilizers and food waste, yellow to represent animal wastes, red to represent oil and gasoline from cars, and coco powder to simulate erosion. Dilute food coloring by adding 1 drop food coloring to every 10 mL of water. Put the food coloring or drink mixes in areas where it might be on their school grounds. Water the model and look what happened to the water. Add in the rain garden and repeat. The sponge (rain garden) will remove a lot of the coloring from the water when the model is rained on again.
4) If you are planting a rain garden on the school site, show students where you plan to install it and compare the location with the one professionals chose. Why did the professional select the spot they chose?

Option 2: Middle School

Objectives: Students will:

1) Use topographic maps to trace the flow of surface water runoff on their school grounds and construct a model of their school site showing how surface water runoff could be trapped in a rain garden and used to recharge underground aquifers.
2) Distinguish a pervious from impervious surfaces;
3) Trace the path of water from precipitation to runoff and storage; and
4) Construct a model to demonstrate how changes in percent impervious surfaces help manage storm water runoff.

Topics Covered: Pervious and Impervious Surfaces, Weather, Precipitation, Flooding, Groundwater Recharge, Erosion, Topographic Maps, Land Use, and Water Pollution

Activity Time: 1-2 class periods

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

Materials:

7.5 minute topographic map of school
Blown up section from topographic map of school grounds
Colored pencils or markers
Masking tape
Plain or graph paper
Pencils with eraser
Clip board
Hose
Bucket
Water source

Follow Up:

Hose
Bucket
Water source
Plain or graph paper
Pencils with eraser
Clip board

Extension:

2 foot x 6 inch boards
Clay or play dough
Half Gallon or Quart water pitcher
Water Source
Plain paper
Pencil with eraser
Clip board
2 gallon bucket
8 quart square container
Other containers (optional)

Introduction:

Begin the same way as the ***No Place to Run*** Grades 3-5 Option Introduction with a discussion of "where does water go when it rains?" Students are going to figure out where on their school yard might be a good location to capture the most water in a rain garden. Students are going to use a topographic map to help them figure out what land area drains to their schoolyard so they can site the rain garden.

Introduce students to topographic maps. Show them a 7.5 minute quadrangle topographic map. This map represents one square of the earth surface. Note that topographic maps are not actually squares or rectangles because of the shape of the earth. Show students a topographic map and then project a topographic map onto a screen for the whole class to view (optional). Look at the lines on the maps. Ask what they think the lines represent? (contour lines, elevations). The brown lines are called contour lines and they show elevations. Look at the map scale to see what the distance is between contour lines? The distance varies but is usually 10 or 20 feet depending on the map. Look for the numbers embedded in the brown lines. This number is the elevation of the land above sea level. Every 5th line has a number in it. The map also includes other features like woodlands and wetlands and these features are green. The black features are building and roads. The pink features are urban areas. The yellow areas are mines and the red areas are landfills. And the purple features are items that have been added to the map since the last edition of the maps and have not been verified. They are going to do an activity to determine the watershed boundary of their school yard and use this to site a rain garden on the property.

Hands On:

1) Divide the class into teams of 4 students and give each team a copy of a section of topographic map that includes their schoolyard and a set of colored pencils or markers. Have students:
   a) find their school on the map and to draw a red circle around it; and
   b) locate streams, rivers, lakes, marshes, and ditches closest to the school site and mark them in blue. Mark the direction of flow with an arrow. Remember water flows down hill. Contour lines going down hill look like “V’s” are usually water channels. Contour lines going uphill that look like “M” are hills.
2) Have students complete the **Topographic Map Orientation Activity.** (See Appendices)
3) Students are going to draw a watershed boundary for the rain garden proposed at their school site. Pass out a copy of a 400% topographic map magnification of just their school site. Find the highest and lowest points on the map using the numbers in the contour intervals and mark them with black “X’s.” Where is the school in relation to the high and low points?
   a) Look uphill from the school and mark all of the hilltops with a black “X.” Use arrows to show which direction the water flows. Where does the water flow in relation to your school? Where does it flow in relation to water bodies around your school?
   b) Where would be the best place on the school ground to put a rain garden? Put and “R” in the proposed rain garden spot and then draw the watershed boundary for the area. Find the highest ground around the school and follow the hilltops and ridges connecting the “X’s” until you finally connect the line to the proposed rain garden site. The outline should look somewhat like a balloon with the knot representing your proposed rain garden site.
   c) Tape their map up on the wall so everyone can look at the drawings. Which rain garden site has the largest watershed (biggest balloon)? Or the smallest?
   d) In general the rain garden will be anywhere from one third to one fifth of the size of the watershed depending on soil types and infiltration rates that they will study later. Given this new information, which location would work the best? Have them develop a list of factors that would affect their decision of what would make the best rain garden site. For example, manageable size; foot, car, and bus traffic patterns; existing landscaping; safety issues; visibility; and proximity to discharge point like storm drain or water body.
4) Take the students outside with their watershed maps showing the proposed locations and have them use their list of factors to pick a good spot for a rain garden. Have each team pick a location and tell the other students why they chose this location. See if the students can come to a consensus. The process they are using is similar to that of the superintendent, principal, teachers, and watershed professionals who make these types of decisions.

Follow-up: Explore where water actually runs to on their school site. Make their own crude map of the school site showing the highest and lowest points. Using buckets of colored water, travel to the highest points on the school ground and pour out the water. Watch to see where the colored water runs to. Mark it on their crude maps. Repeat this procedure as they travel downhill marking their findings on the crude map. Pass out the topographic maps they marked up during the Hands On portion of this activity and have students compare what they found out as they traveled around the site with the arrows placed on the topographic maps. Is the water going where they thought it would? Why or why not? Then check the date on the topographic map. When was it made? Could there be elevation changes on your school site that are not marked on the map? Discuss how maps are a tool to be used in combination with actual site visits or ‘*ground truthing’*. Mention that topographic maps are updated every 10-20 years on average.

Extension: Create a watershed model of the proposed Rain Garden site at your school following the directions in the High School Option of the ***No Place to Run*** lesson Hands On 4.

Option 3: High School

Objectives: Students will:

1) Distinguish a pervious from impervious surfaces;
2) Use a topographic map to draw the watershed that contributes runoff to their school site, trace the flow of precipitation over the school grounds, calculate slope, and develop a model showing options for capturing and storing rain water on the school grounds including rain gardens and rain barrels;
3) Construct a model to sell rain garden project to school administrators and parents;
4) Determine what it would cost to implement a rain garden project and summarize in a proposal; and
5) Use model to demonstrate how rain garden work.

Topics Covered: Pervious and Impervious Surfaces, Weather, Precipitation, Flooding, Groundwater Recharge, Erosion, Topographic Maps, Land Use, and Water Pollution

Activity Time: 1-3 class periods

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

Materials:

7.5 minute topographic map of school
Topographic Map Activity Directions
Pencil with eraser
Clip board
Clear acetate sheet with Dot Grid printed onto it
Dry erase markers
7.5 minute topographic map of school
Access to copier
Scissors
Cardboard, foam core boards, or foam craft sheets
Colored paper or foam craft sheets
Glue or spray adhesive
Colored markers

Follow Up:
None

Extension:
Pottery clay, Paper Mache, or soil from school yard
Clear plastic wrap or clear acrylic paint or varnish
Permanent markers
Source of water
Sprinkling can
Watershed Boundary Map from Hands On activity
Colored markers
Model from Follow Up
Felt
Sponges
Eye Dropper
Water Source
Drink Mix
Food Coloring
Oil

Introduction:

Begin inquiry with a discussion of “where does water go when it rains?” Then lead a discussion about how water runs off the land. Answers will vary but should include that rain soaks into the ground, runs over the land to a water body, runs down the roads into storm drains, etc. What happens to the water that falls on their homes or the school? Discuss how gutters capture the water and direct it to the street where it flows into storm drains that run into the river. What happens when we have a particularly heavy rain? Why do some streams flood and rivers overflow or flood? Think about reasons that water flows over the ground instead of soaking into the ground. Talk about how some surfaces are pervious and some are not (impervious). Mention that even some pervious surfaces can become impervious under certain conditions like when the ground becomes saturated with rain and cannot absorb more water.

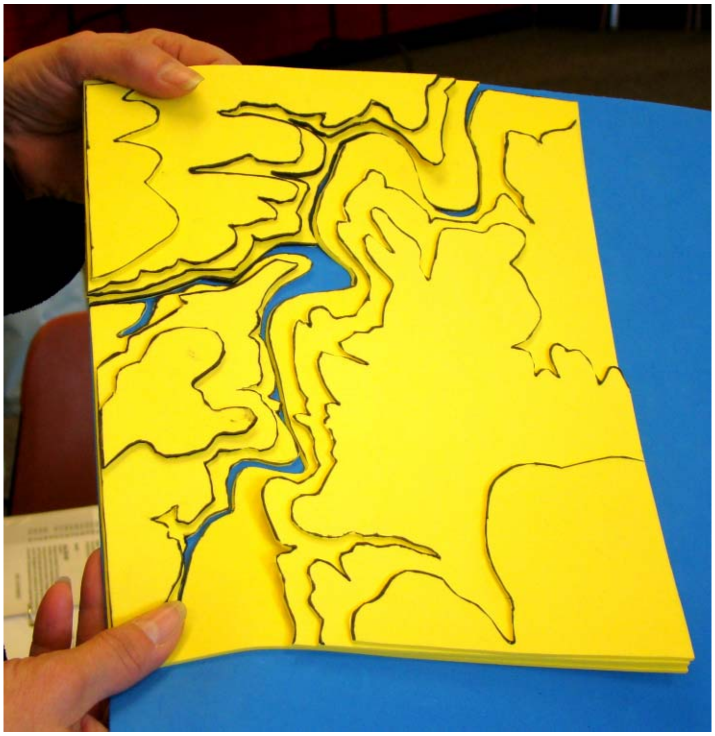
Introduce the students to topographic maps. Show them a 7.5 minute quadrangle topographic map. This map represents one square of the earth surface. The earth is divided into squares by horizontal and vertical lines. The vertical lines are *Meridians of longitude* are north-south lines connecting the poles and the horizontal lines *are Parallels of latitude* are east-west lines parallel to the equator. Meridians and Parallels are circles that have 360 degrees, 60 minutes per degree, and 60 seconds per minute. There are 3,600 seconds per degree. A topographic map is one 15 x 15 minute square of the earth that has been created from aerial photographs to show 3-dimensional features of the earth’s surface. Locations on the earth are expressed as degrees, minutes and seconds. For example, 39° 8' 8.5" is equal to 39 degrees, 8 minutes, 8.5 seconds Latitude. To describe your location on the earth you need the longitude and latitude coordinates. For example, Avey's Run at Cincinnati Nature Centers is 39° 7' 56.3" Latitude and 84° 15' 21.9"longitude.

If you wish to use free online maps for this activity, visit: http://terraserver-usa.com/ or http://mapserver.mytopo.com/homepage/index.cfm?CFID=3692819&CFTOKEN=19169154.

Hands On:

1) Divide the class up into teams and give each team a topographic map of their school. Have students:
   a) Locate the school on the map.
   b) Determine the longitude and latitude coordinates of their schools front door (optional) on the topographic map. Note the vertical line on the left of the map is marked for latitude and the horizontal line at the top of the map is marked for longitude. Use a straight edge to find the horizontal and vertical coordinates When students have figured this out, visit the front door and use a hand held GPS to determine the coordinates. Compare them with the coordinates the students determined using the topographic map. With the coordinates from the GPS Unit Were they close? Why or why not?
   c) Review the features of topographic maps including contour lines and the color coding. See background section for more information. Have them complete Topographic map Orientation Activity from Middle School Option (optional).
2) Select a location on the school site they think would be the best place to put a rain garden using directions in the ***No Place to Run*** Middle School Option Hands-On Section Step 3.
   a) Draw the watershed boundary for that site.
   b) Use a dot grid to determine the size of the watershed area for that rain garden and write this number on their maps. The directions for using the Dot Grid are on the handout. (See Appendices for **Dot Grid Master**.) If the topographic map was blown up 400%, be sure to blow up the Dot Grid Master 400% when you make the transparencies for the activity.
3) Complete ***No Place to Run*** Middle School Option Hands-On Section Step 4. Evaluate each rain garden location and select one location. What factors did their place the most weight on and why?
4) Assume students need to "sell" the idea of a rain garden to their school administration (principal, superintendent, school board) and the community. To do this, create a 3-dimensional model like architects and landscape designers use to sell their ideas. Use the watershed boundary map created in step 2 of this activity and their preferred alternatives of where to locate a rain garden using information from step 3 of this activity. This model will show where a rain garden could go. It could also be used in a presentation along with a written proposal to fund a rain garden project at their school (optional).
   a) To create the watershed model, blow up the topographic map section of a copier to 400% larger or more than its original size. Be sure to keep scale in mind. For example, if original topographic maps is 1 inch = 24,000 feet. In the blown up version, 1 inch = 240 feet. Using this information, make your rain garden to scale. For example, a 400 foot x 400 foot garden would be 1 ¾ inch by 1 3/4 inch.
   b) Use a material like card board, foam core, or foam sheets to make the layers. Use push pins to secure the map to the material you chose.
      i) Place the photocopy of the topographic map on top of the foam core, cardboard, or foam sheet.
      ii) The model is created starting with a flat base. Each layer is an elevation on the topographic map and you start with the lowest elevation and add each new elevation as a separate layer. For example 820 feet might be the lowest layer and then add on 830, 840, 850, and so on until the model is complete,
      iii) Carefully cut along the dark contour line with the number in it representing the **lowest** elevation. Label the center of the construction paper with a "1." This is the first level of the model which you will build. Set aside the layer.
      iv) Now you are ready for the next elevation. Place the photocopy of the landform on top of another sheet of foam board, cardboard, or foam sheets (the color you use does not matter) and carefully cut around the next dark contour line with the number in it. Label the center of layer with a "2". This is the second level of your model.
      v) Repeat this procedure until you have cut out all of the contour lines. Don't forget to label the layer with the appropriate number.
      vi) Now you are ready to build your 3-D model.
      vii) Take layer number 2 and glue the spacers to the bottom of the layer (optional). The spacers represent the increase in elevation between each contour line (contour interval).
      viii) Glue layer 2 onto the top of the first layer.
      ix) Repeat Step 6 and 7 with the rest of your layers until you have built your model.

c) Make 3-dimentional models of the schools other features like buildings, trees, bushes, flag poles, cars in the parking lot etc. and glue them to the landscape.
d) Use colored markers to draw in the flat features like parking lot lines, road, grass, etc.
e) Cut out a separate piece that shows the proposed rain garden location and glue it to the model. Color the rain garden using permanent markers to show colorful plants.
f) Be sure to label the final model with names of the school site, buildings, roads, other features, and rain garden.
g) Place the model in a prominent location where it can be viewed by faculty, staff and students. Have the students devise a way to get feedback on their model and proposed plan.



Follow Ups:

1) Find out what it would cost to create a rain garden and write a written proposal to create a rain garden on their school site.
2) Make a presentation to school officials and/or the PTA about their idea.

Extensions:

1) Using the basic watershed cardboard or foam core model created in the ***No Place to Run*** High School Option Hands On section, and cover it with clay (or dirt from the school ground) and apply it to the bare model so the surface looks like the actual topography of the school yard. Locate the proposed rain garden location using the map and create the garden. Use a serrated knife to excavate and make your flat-bottom bowl shape. Remember that the garden needs to be oriented perpendicular to the water source. Use additional clay to form the berm around the garden to trap the water. Then make models of the buildings, roads, etc. with paper and permanent markers. Use small pieces of paper to label all the features including the rain garden. Place the model over a towel (or take the model outside on the grass) to capture any water that runoff off and use a sprinkling can to simulate rain and rain on the model. Students will see how rainwater runs from the highest points toward the lowest. Generally a body of water, such as a lake or river and in this case rain garden is formed at the lowest point. Observe where water went on their model? Was this a good location for the rain garden? What modifications would they make? Tell them in an actual garden, the water would soak in!
2) Demonstrate how many inches of rain your rain garden could hold by modifying the lands surfaces to represent pervious and impervious surfaces. Take the watershed boundary map of the site the student's selected and then give a copy to each team and some colored markers. Have students that they evaluate the

watershed in terms of pervious and impervious surfaces and use the colored markers and a key to label their maps according to how pervious the land is. For example, bare ground has a different porosity than a grass area. Go outside and label their maps coloring in the sections according the land use. Given what they know now, have they selected the best location for their rain garden? Why or why not? Using this information, modify the watershed model. Leave the impervious areas as modeling clay and add felt to cover grass areas. Cut away the clay and sink in small sponges for trees and make landscape beds out of sponges the approximate size of the bed using the map scale as a reference. Then put a sponge inside the rain garden. Using an eye dropper, rain on the landscape in varying amounts representing rainfall events. Depending on the size of your model, select an appropriate amount of water for rainfall amounts. For example, 1 tablespoon = 1 inch and 2 tablespoons equals 2 inches. How well did the rain garden perform?

3) Extend the demonstration to show students how pollution created by common substances such as automotive fluids, garden fertilizers and pet wastes can be carried by rainwater into the lake or river. Dry off the model with a towel and then sprinkle food coloring or drink mix onto the model in locations where you might find it. For example, use red food coloring or drink mix to simulate automotive fluids, green to simulate fertilizers, brown or yellow to simulate pet wastes. Then rain on the model again. Where did they go? Into the Rain Garden? Tell them that one of the functions of a rain garden is to filter out pollutants so they do not travel through storm drains untreated into rivers, lakes, and streams.

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.

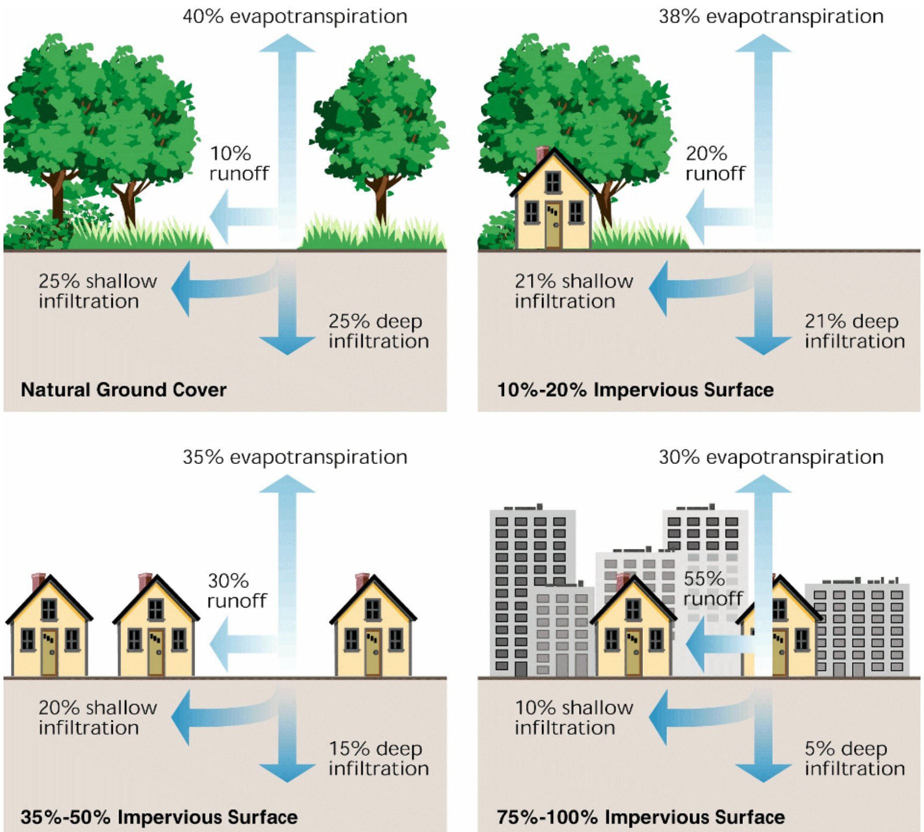


Fig. 3.21 -- Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
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 flood. 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 that 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. Next 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 size of the building in square feet 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

<u>Calculating Depth</u>
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 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:

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

<u>Calculating Volume</u>
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, the 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 multiple 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:*** A variation of the soil type method is to use 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 the 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 the simple map to create a 3-dimensional model of the school and have the students experiment with different sizes and shapes or rain gardens to see which size and shape of rain garden captures and stores water best; and.
3) 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, 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, orientation, 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 is the independent variable?
   a) To test the shapes of the rain gardens, what variable(s) need to be controlled? (size of sponges needs to be the same, orientation needs to be the same, amount of water needs to be the same, the slope needs to be the same, and the 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 needs to be the same, shape of the sponges needs to be the same, amount of water needs to be the same, the slope needs to be the same, 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 needs to be the same, orientation needs to be the same, the amount of water needs to be the same, 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 local 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 that 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 the actual 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*** Middle School lesson and 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 to their rain garden. 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. For this reason, more water runs off the land. 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, using the downspout area example above, if the slope from the downspout to the rain garden is 6% or less, you would multiply 768 square feet times the depth of the rain garden or 0.5 feet (6 inches divided by 12) to get: 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.

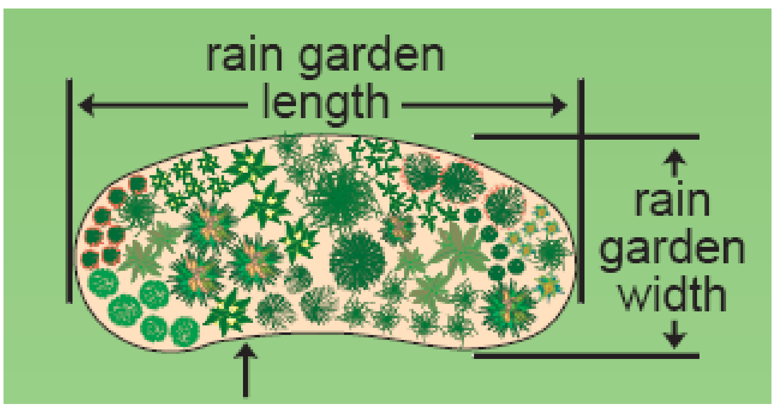


Illustration Source: Rain Gardens A How to Manual for Homeowners, UW-Extension offices, Cooperative Extension Publications, University of Wisconsin, 2003.

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 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;
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 Tools instead to calculate the watershed area draining into a point that you have selected on an interactive map. It is available for the 6 states in EPA Region 5 (Indiana, Illinois, Wisconsin, Minnesota, Michigan, Ohio). Once you have obtained a 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/~watergen/#1)**

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 below (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.

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 type 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 percent water, 25 percent air, and 5 percent 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. Then let the cones 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.

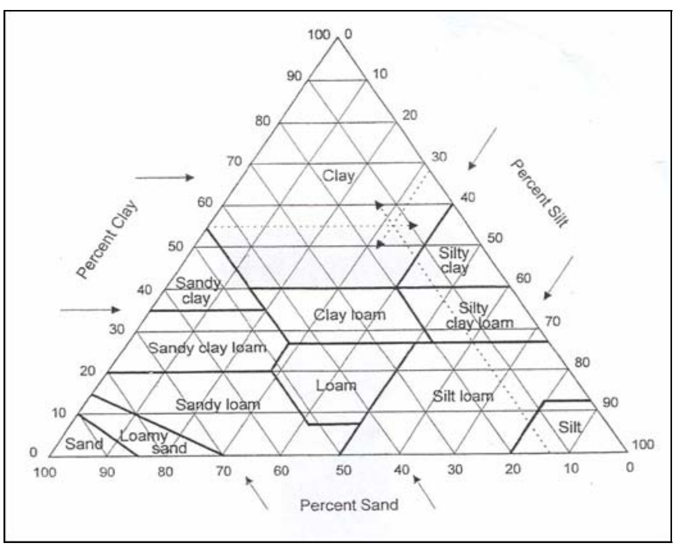
Soil texture determines the soil's porosity because it dictates how much space there is between the particles. The spaces between particles are usually filled with air or water depending on weather conditions. For example, if soil is sandy, it will drain quickly. If soil has a lot of clay, it may drain 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 one 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:

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

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 demonstrate the porosity of several soil types;
5) Conduct and experiment 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, Perk Test, 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 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 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). They are going to look at different types of soil using a microscope with a 10X power lens. Then they are going to conduct an activity to find out what is in their schools soil 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.

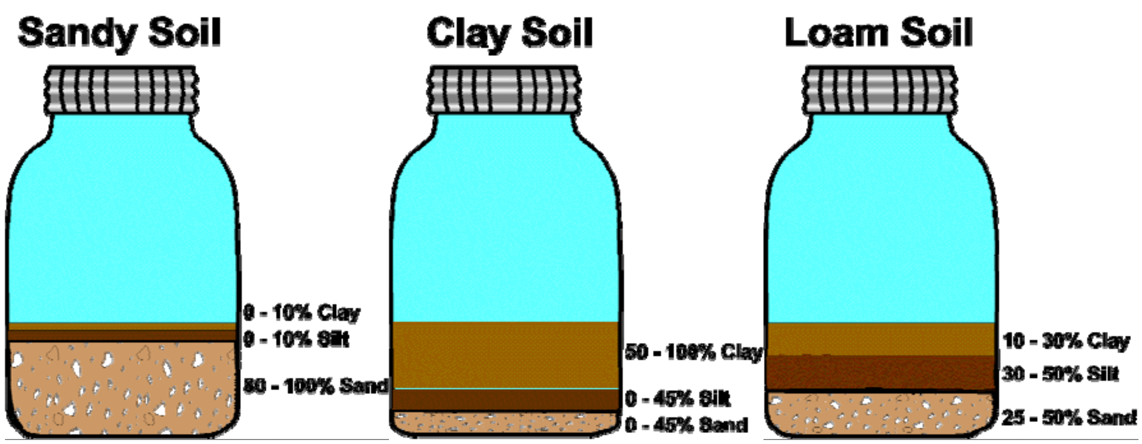
Hands On:
1) Take a clump of soil and spread a thin layer of this soil onto a small dish and put it under the 10X power on a microscope or use a 10X hand lens to view it. What did they see? Draw a picture of what they saw and label the picture. They should be able to see particles of different sizes 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 plant
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 wet or cool but can harden and crack when dry and hot. Clay also tends to hold 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). They are going 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/1/4 clay.

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/1/4 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 and 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; and
7) 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
Microscope or 10x hand lens
Teaspoon measure
Key to Soil Texture by Feel
Water
2 liter bottles
Card board box
Scissors or box cutter
Measuring cup
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. Then they are going to blend their own soil mixes to test its porosity.

Hands On:

1) Have students work their soil clump in their hand 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 chart 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 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 below). 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 to mimic natural conditions. Remind the students that the soil has to drain at least 1 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? 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 demonstrate the porosity of several soil types;
4) Conduct and 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:

Trowels
Rulers
Popsicle Sticks
Index Cards
Pencils with erasers
Watch with second hand
Water
Sprinkling Can or hose
Calculator
Cardboard box
2 liter containers
Sand
Compost
Soil for School Site
Measuring Cup
Masking Tape
Permanent markers or ink pens

Follow Up

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

Extension:

Nine 2 liter bottles
Plant Plugs of 3 different varieties
Measuring cup
Water
Fertilize

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 are a good resource for soils information. 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. Also, 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 the unfilled buckets. 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 the students conduct the ***How Deep Will It Flow*** Middle School Option Hands On Step 2 only 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 planted them. Did this make a difference?

Lesson 4: Put on Your Design Cap

Lesson Overview:

Purpose: To help students understand how to design a rain garden assuming that the students have selected the location, size, shape, and soil mix for their garden in the previous lesson.

Background:

Designing a rain garden on the school grounds is an exciting process that improves the quality of water, provides wildlife habitat, and offers students a learning lab where they can learn more about plants, butterflies, bees, and birds. When locating the garden, it is important to observe the drainage patterns and where water naturally runs over the ground. The rain garden should be located downstream from the flow or near downspouts that collect water draining from a roof. To avoid drainage issues, rain gardens are always located at least 10 feet from any foundation and well away from underground lines or pipes. It is best to call the 'Oops' phone number when you are considering locations so they can mark all of the underground utilities before you select a final site. If you are planning to capture large amounts of runoff from large parking lots or roads it is best to consult an engineer to aid you and your students with the design.

From a design perspective it is important to consider the surrounding landscape. Successful rain garden projects blend in with the surrounding landscape and relate to the other landscape features. Rain gardens are typically shaped in rounded shapes like ovals, kidney beans, and even dumb-bell shapes. When selecting a shape, it is a good idea to use a hose or a long rope to lay out the proposed shape onto the ground. Then stand back and look at the shape from various angles to see if it is going to look good from every angle. If possible, leave the hose or rope laid out and visit the proposed site at different times of the day and make notes. Is the garden sunny all day or is it shaded by buildings and trees during a portion of the day. Observe the foot traffic through the area. Do people use the proposed site as a cut through or for another purpose? Is there a purposes other than storm water control for the rain garden? Is it important for the rain garden to attract song birds, butterflies, or bees? Is it important for the rain garden to have a theme such as a scent garden, herb garden, edible garden, or garden with another theme? Is there already a color scheme established near the rain garden that needs to be matched?

Next, it is time to consider what plants work well in rain gardens and grow well in the area. Consider sunlight availability, moisture requirements, aggressive or invasive behaviors, and hardiness. Plants are very important in rain gardens because their roots loosen the soil, allowing oxygen and water to penetrate. Plants improve drainage in rain gardens as they mature and also help wick moisture from the soil through transpiration. Roots also hold soil together and help prevent erosion. Different plants have different types of root systems. Plants with deep and bushy root systems are ideal for rain gardens. Native plants are a good choice because they are adapted to your climatic conditions, have deeper root systems, and require less maintenance. Non-natives can be used but it is best to plant hardier varieties that have strong root systems. Plants in rain gardens have to tolerate extreme conditions from inundation with water, prolonged wet periods in the spring, to long dry spells in the summer. Unlike typical perennial gardens, rain gardens are not typically watered or fertilized on a regular basis so it is import to choose really hardy plants. It is also a good idea to select low maintenance plants, not invasive, and are deer resistant if you school is in a wooded community.

Now it is time to consider the design process. Rain gardens are typically designed with flat bottoms but some areas of the garden will be naturally wetter than others. For example, where the water flows into the garden or the inlet and sometimes the outlet or area near the berm are wetter than other areas. After inundation rain gardens typically dry out around the outside edge and work their way to the middle making a "target" pattern with the center being the wettest, the outer edge the driest, and the middle portion evenly moist Rain gardens planted on leveled out areas on slopes, the rear edge near the berm is often wetter. It is a good idea to consider moisture zones when siting plants.

The next step is to select the actual plants. Each plant has a different set of requirements for optimum growth and they all have different heights, spreads, bloom times, bloom colors, seed or fruit type, and winter character. Different plants also attract different birds, butterflies, bees, deer, rabbits, etc. So it is a good idea to research plants beforehand and select the best choices for your purposed. Now it is time to lay out the planting scheme. There are existing layouts to select from that can be adapted to your area or students design a custom layout. To do this, draw the garden site on graph paper to scale. Be sure to note important thinks like shading and building or walkway locations. Then make a list of potential plants. Just like furniture placement schemes for the home, circles of plant types can be draw to scale showing the plants spread. Drinking straws can be scaled to the mature heights of the plants glued onto the circles so height can be considered in the design process. If desired, the plant representations can be colored to show bloom color. Bloom time can be written on the circle or the back of the circle if having a garden with multiple seasons of bloom is important. To show moisture preferences, put a W for wet, a D for dry, and an M for moist on the circles. Then move the plant representations around in the space to see what works well. As a general rule, graduate the heights of the plants so they do not shade each other out. One option may be to go from front to back with short to tall plants. Another option may be to start in the middle with tall plants and graduate to the edge with shorter ones. Gardens also look better when they are planted fewer varieties so there are masses of color and texture. Choose 3 or less plant bloom or foliage colors, and plant the plants in larger groupings or clumps. The more plant types and colors, the more "wild" (or cottage style) the garden will look. When students have designed a garden they think will work, glue the plants onto the graph paper or re-draw the rain garden bed design to scale. Then make a complete list of the plants including the botanic names so the plants can be purchased them at a nursery. Nurseries prefer botanic names to common names so be sure to take both names with you and a picture of the intended plants if possible to avoid confusion It is also a good idea to select alternative plants in advance in case the plants you selected are not available.

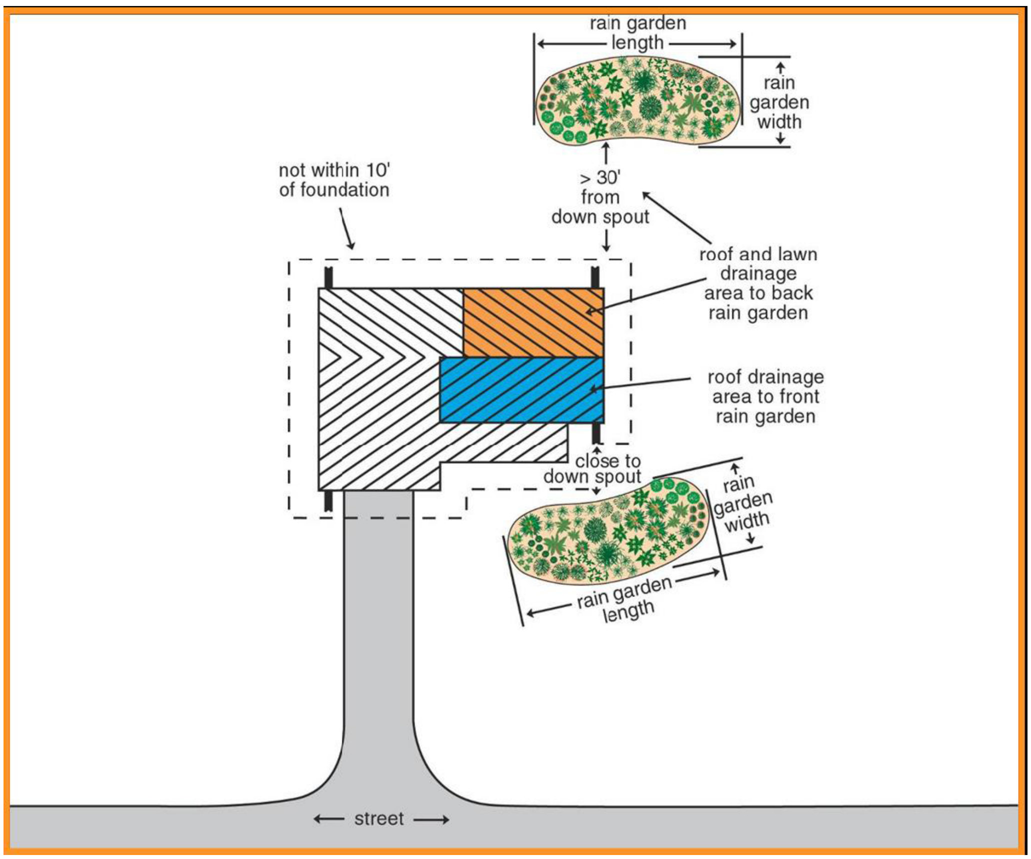


Illustration Source: Rain Gardens A How to Manual for Homeowners, UW-Extension offices, Cooperative Extension Publications, University of Wisconsin, 2003.

Lesson Descriptions:

Option 1: Elementary School

Objectives: Students will:

1) Conduct a site evaluation of their rain garden site to determine slope, sun exposure, water inlets and outlets, wet and dry zones, and other factors such as proximity to buildings and windows that will influence their design;
2) Develop a list of design criteria for their garden including color schemes, shade tolerance, garden height, plant types (shrub, grasses, perennial), plant maintenance requirement, and other desired uses such as butterfly garden, wildlife garden, scent garden, edible plant garden, etc;
3) Use a hose or line to create the rain garden shape on the actual school grounds and make a map to scale of the garden shape and size including water inlets and outlets;
4) Use landscape paint to mark their final shape on the grass;
5) Using a list provided of plants available, research which plants would work in the garden and meet the criteria;
6) Working in teams, design the garden in color on paper and critique the designs as they relate to the design criteria;
7) Create a 3-dimensional model of the garden that shows plant height, color, shape, spread, and spacing between plants; and
8) Work with a professional landscaper to critique their designs and select one design to install at the school.

Activity Time:
1 class period

***Topics* Covered:** Problem Solving, Experimental (Rain Garden) Design, Garden Themes, Plant Selection Criteria, Garden Orientation, Design Evaluation Criteria, Modeling, and Oral and Written Presentations

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

Materials:
Reference books on rain garden plants
Plant list of rain garden plants for this area
Access to computer connected to internet
Hose or string
Graph paper
Colored construction paper (optional)
Clip Board
Pencils with erasers
Colored Markers or crayons
Scotch Tape
Glue Sticks
Plastic Straws

Follow Up
None

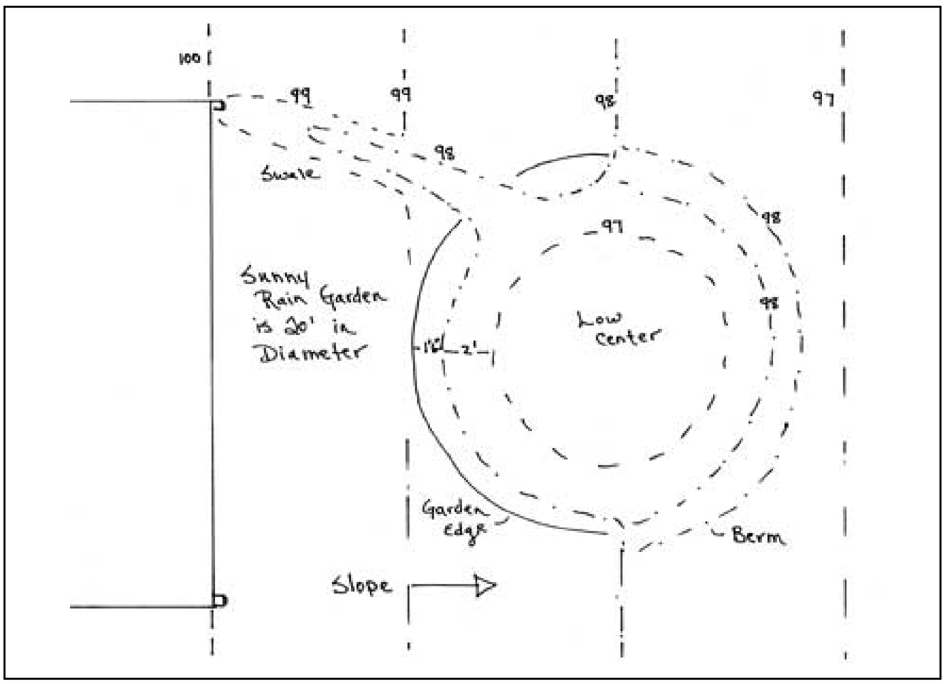
Extension
Poster board
Pictures of plants
Scotch Tape
Glue sticks
Colored construction paper

Introduction: It is time to work on designing the rain garden. The first thing they need to do is to figure out what kind of rain garden they want. Have students suggest rain garden themes. Once a theme is selected, ask the students what they need to do next? (learn more about gardens with the theme they have chosen)

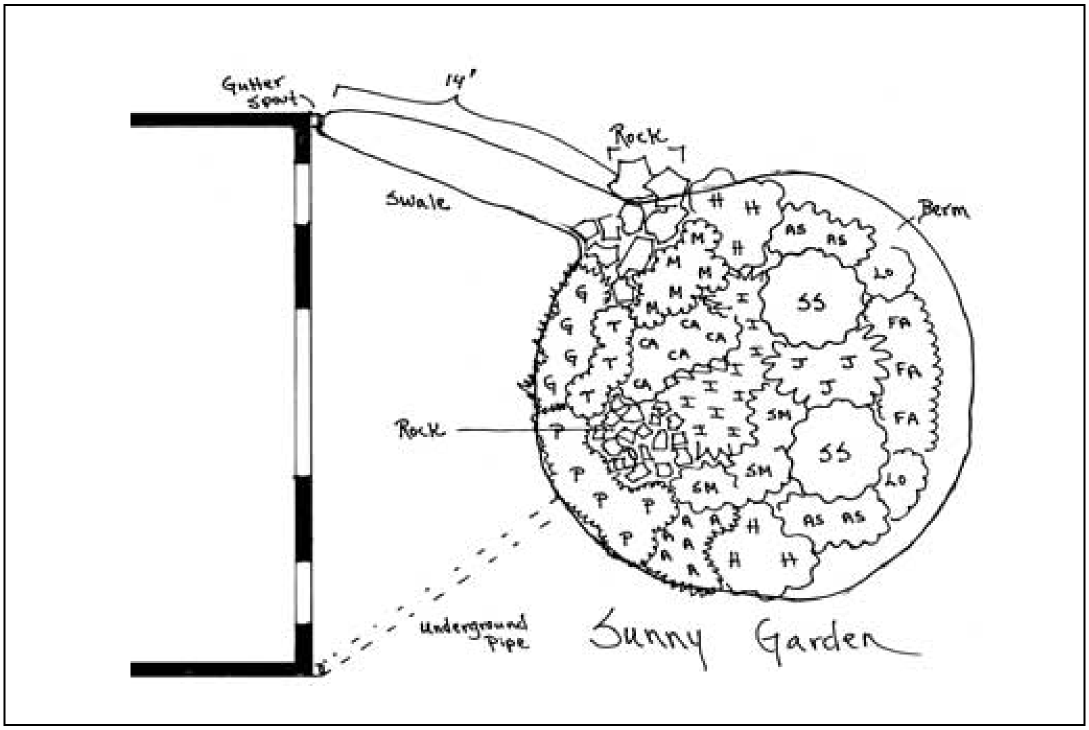
Hands On:

1) Conduct research into their garden theme. What types of plants go with their theme? Do they need to add other items to the garden besides plants (water bowl or resting box for butterflies, nesting boxes for birds, etc.)? Generate a list of plants they like or might work for their garden.
2) Assign the responsibility of researching one or more plants for the rain garden to each student. Have them check the internet, nurseries, and libraries. Find out the following: Plant name, botanic name, height, spread, bloom time, bloom color, sun/shade preference, moisture requirement, and use in the theme. Put all of their information and a picture on a single page and tape them up in the classroom for everyone to use as a reference.

3) Visit the rain garden site and use a hose or string to layout the garden. Look at the garden from every angle. If they like the layout, have them make a sketch. Locate a point in the center and measure to the edges so they can re-create their drawing to scale when they return to the classroom.
4) Have students work in teams and recreate the layout on a piece of graph paper noting sun/shade area and proximity to buildings, walkways, and other prominent features.



5) Have students select plants they like and make models to scale. Label the models with the name, sun/shade preference, moisture requirement, and bloom time. Color the model with the bloom color. Cut out pieces of straws and to glue to the center of each to represent the height. Have the students experiment the layouts. When they have a layout they like, have them glue down the pieces and put the designs up on the wall.
6) Have each team present their design to the class, explaining why they designed the garden the way they did. Did the class prefer any one design? If not how would they modify the designs? Have the class work as a team to come to consensus on a design. Then re-assemble the winning design and put it up in the classroom for all to view.



7) Make a list of plants to purchase.

Follow-up: Have a landscape design professional review the designs created by the class and critique them. Are the plants they selected placed in the right place in the garden to do well? Are their plants that might work better in this area. Are their good plants that relate to the theme that they have not considered. Based upon this critique have the students modify the design.

Extension: Choose one or more themes and have the students work in teams to design rain gardens with various themes. Have the class critique the designs and the teams use the critiques to create final designs. Have students make posters with their designs and pictures of the plants including a brief description of the theme and plants used. Then place the garden designs in a hallway with a box so teachers and students in the schools can cast their vote for the winning design. Tally the results and plant the selected design.

Option 2: Middle School

Objectives: Students will:

1) Conduct a site evaluation of their rain garden site to determine slope, sun exposure, water inlets and outlets, wet and dry zones, and other factors such as proximity to buildings and windows that will influence their design;
2) Develop a list of design criteria for their garden including color schemes, shade tolerance, garden height, plant types (shrub, grasses, perennial), plant maintenance requirement, and other desired uses such as butterfly garden, wildlife garden, scent garden, edible plant garden, etc.;
3) Use a hose or line to create the rain garden shape on the actual school grounds and make a map to scale of the garden shape and size including water inlets and outlets;
4) Use landscape paint to mark their final shape on the grass;
5) Using a list provided of plants available, research which plants would work in the garden and meet the criteria;
6) Working in teams, design the garden in color on paper and critique the designs as they relate to the design criteria;
7) Create a 3-dimensional model of the garden that shows plant height, color, shape, spread, and spacing between plants; and
8) Work with a professional landscaper to critique their designs and select one design to install at the school.

Topics Covered: Problem Solving, Experimental (Rain Garden) Design, Garden Themes, Plant Selection Criteria, Garden Orientation, Design Evaluation Criteria, Modeling, and Oral and Written Presentations

Activity Time:
1-2 class periods

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

Materials:
Reference books on rain garden plants
Plant list of rain garden plants for this area
Access to computer connected to internet
Hose or string
Graph paper
Colored construction paper (optional)
Clip Board
Pencils with erasers
Colored Markers or crayons
Scotch Tape
Glue Sticks
Plastic Straws

Follow Up
None

Extension
Topographic map of school site
Cardboard, Foam core board, or craft foam sheets
Utility scissors, dry wall saw, serrated knife or jig saw
Wood rasp
Hot glue gun with glue sticks or craft glue
Sand
Silk plants
Colored construction paper of craft foam sheets
Acrylic paints
Craft paint brushes (various sizes)
Permanent markers

Introduction: Discuss the steps in designing a rain garden and ask if rain gardens can serve dual functions. For example, the Rain Garden might be used to attract birds, butterflies, or wildlife. Discuss design criteria and develop a list of criteria for their rain garden. Based on their criteria, have the students research out plant species and select the appropriate plants for their purposes. Then the students will construct an architectural model of their rain garden design.

Hands On:

1) Visit the rain garden site and make notes about the site. For example, they need to consider sunlight availability, moisture requirements, aggressive or invasive behaviors, and hardiness. If possible, visit the rain garden site every hour and record how the sunlight changes at different times of the day.

2) Use a hose or string to layout the garden. Look at the garden from every angle. If they like the layout, have them make a sketch on graph paper. Have them locate a point in the center and measure to the edges so they can re-create their drawing to scale when they return to the classroom.
3) Return to the classroom and have the students evaluate what purposes they want the rain garden to serve in addition to storm water management. Based on their purpose or purposes, develop a list of criteria for their design. For example, if they are in an area with a deer problem, the criteria might be deer resistant plants. If the garden is at the main entrance of the school, the criteria might be formal manicured appearance. If there is already an established color scheme, the criteria might be plants with those colors. Or if the garden is 50% sun and 50% shade, the criteria might be shade plants on the north side and sun plants on the south side.
4) Next, students will complete a Rain Garden Plant Selection Worksheet to help them understand the environmental conditions at their site and the plant requirements (see Rain Garden Species Selection Criteria Worksheet in the Appendix).
5) Make a list of plants students think may work well in their garden and assign the responsibility of researching one or more plants for the rain garden to each student. Check the internet, nurseries, and libraries. Have them find out the following: Plant name, botanic name, height, spread, bloom time, bloom color, sun/shade preference, moisture requirement, and use in the theme. Complete the Plant Evaluation Table. Optional: Have the students put all of their information about a single plant and a picture on a single page and tape them up in the classroom for everyone to use as a reference. (see Plant worksheet in Appendix).
6) To create the actual design, divide the students into teams and give each team all of the plant and design criteria information. Have each team develop a design on paper. Post their designs and have the class vote for one of the designs.
7) Using the winning design, develop a list of plants to order.

Follow-up: Have a design professional visit the class and critique your rain garden design. Using this input, have the students modify the design.

Extension: Have the students create a 3-dimensional model of the winning rain garden design to share with the school, parents, and community. Decide on the model scale. Then create the basin in the same way they created the topographic map model in the No Place to Run High School Follow Up using foam core board. Find the area on the topographic map where the rain garden will be located and enlarge that section so that the rain garden is at least 9 inches by 12 inches or the size chosen. Have Start from the largest layer and work to the middle cutting out all of the layers. Then glue the layers together. Use a wood rasp to file off the edges and then paint the model with glue and sprinkle with sand as a base. Make structures like the school out of cardboard and paint them. Paint the sand to show parking lots and roads. Use pieces of silk plants to represent the plants in the rain garden.

Option 3: High School

Objectives: Students will:

1) Conduct a site evaluation of their rain garden site to determine slope, sun exposure, water inlets and outlets, wet and dry zones, and other factors such as proximity to buildings and windows that will influence their design;
2) Develop a list of design criteria for their garden including color schemes, shade tolerance, garden height, plant types (shrub, grasses, perennial), plant maintenance requirement, and other desired uses such as butterfly garden, wildlife garden, scent garden, edible plant garden, etc.;
3) Use a hose or line to create the rain garden shape on the actual school grounds and make a map to scale of the garden shape and size including water inlets and outlets;
4) Use landscape paint to mark their final shape on the grass;
5) Using a list provided of plants available, research which plants would work in the garden and meet the criteria;
6) Working in teams, design the garden in color on paper and critique the designs as they relate to the design criteria;
7) Create a 3-dimensional model of the garden that shows plant height, color, shape, spread, and spacing between plants; and
8) Work with a professional landscaper to critique their designs and select one design to install at the school.

Topics Covered: Problem Solving, Experimental (Rain Garden) Design, Garden Themes, Plant Selection Criteria, Garden Orientation, Design Evaluation Criteria, Modeling, and Oral and Written Presentations

Activity Time:
1-3 class periods

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

Materials:
Reference books on rain garden plants
Plant list of rain garden plants for this area
Access to computer connected to internet
Free, shareware, or trial versions of landscape design software
Hose or string
Graph paper
Colored construction paper (optional)
Clip Board
Pencils with erasers
Colored Markers or crayons
Scotch Tape
Glue Sticks
Plastic Straws

Follow Up
None

Extension
Access to computers and internet
Access to power point software
Access to computer projection system

Introduction: Introduce the project the same way as in the Middle School Option

Hands On:

1) Repeat steps 1-5 of the Middle School Option.
2) Instead of Designing the Rain Garden on paper as they did in Step 6 of the Middle School Option, have the students design the rain garden using their computers using free online landscape design software like http://www.showoff.com/; or take advantage of free trials of Landscaping Programs such as www.ideaspectrum.com. New programs are being offered all the time so have your students conduct an

online search for free or free trail garden design software. You might also contact a nonprofit gardening organization or local landscape architects in your area to see if they have an online garden program that your students could use.

3) Repeat step 7 of the Middle School option.

Follow-up: Follow up the project the same way as in the Middle School Option

Extensions: Have the students develop a power point presentation of the winning design to share with the rest of the school, their parents, and the community.

Lesson 5: Get Down and Dirty

Lesson Overview:

Purposes: To help students understand:

1) Steps involved in planting the rain garden including site excavation, installation of under drains and/or modified sumps (optional), soil amendments, tillage, drainage testing, planting, and mulching.
2) How to plant a plant,; and
3) How to apply mulch.

Background:
Planting your rain garden is a very special event. Not only is it the culmination of hours of planning and research it is also an opportunity to get everyone at the school and your community involved. One way to get everyone involved is to have a dedication ceremony to break ground before planting or after the garden is complete to recognize the participants and their efforts.

A successful planting day requires advances preparation.

1) <u>Order Plants</u>: Depending on your budget, select plants that are in pint size (4 inch) to 1 gallon size (8 inch) pots if possible. Plugs (2 inch) can be used but the rain garden will need to be planted in the spring and watered regularly until the plants become established. It is a good idea to order the plants as far in advance as possible. Depending on the circumstances, either pick up the plants or and have them delivered. To assure the plants remain healthy, do not pick up or have plants delivered more than a week before planting. Keep potted plants in the shade and water as needed until planting day.

2) <u>Order Soil Amendments:</u> Soil amendments also need to be ordered in advance. Depending on the size of your rain garden, order in bulk by the cubic yard or purchase amendments in bags. Bulk amendments are cheaper than bagged but more difficult to maneuver. Pick them up or have them delivered. If they are picked up by a person with a truck who works at the school, it may be able to store the amendments in the truck. Because soil amendments are heavy, plan to store the amendments as close to the garden as possible on a paved surface if possible. If they need to be stored on the ground, put a tarp down to separate the amendments from the grass. It may be necessary to re-seed the grass where the amendments have been stored if you store the amendments for more than a day or two.

3) <u>Layout Garden:</u> To layout the rain garden bed, use 100 foot measuring tape to measure out the approximate shape of the bed and then use a hose or long line to actually create the shape of the bed. When the groups is happy with the shape of the bed, use landscape paint to mark the bed shape on the ground. Now the bed is ready to be excavated.

4) <u>Borrow Equipment:</u> If the school chooses to excavate the soil, they may want to consider renting a backhoe if the garden is large. If the garden is smaller, students can dig it out with pointed shovels. Loosen the soil to a depth of 12-18 inches before adding the amendments. A rototiller works well for this but students can use pitch forks and shovels to accomplish this too. Use a rake to smooth out the bed after the amendments have been added and before planting. A rake can also be used to smooth out the mulch after planting. Several pointed shovels and trowels are needed to dig holes for the plants depending on the size of the plants. Several large buckets are handy to transport soil amendments and mulch. Wheel barrels are also good for transporting mulch and soil. Garden gloves are desirable, but optional.

5) Arrange for Excavation (optional): If planting a larger garden, arrange for the garden to be excavated by landscape professionals. Also arrange for them to rototill and to amend the soil. School maintenance staff or the town's local public works department may be able to provide this service for little or no cost. If the garden requires underdrains, it is best to have them installed professionally when the soil is excavated.

6) Excavate the Garden: It is a good idea to excavate the garden on one day and plant it on another day, but everything in one day. The advantage of excavating and amending the soils in advance is that you can test the drainage before you plant the garden. When excavating with shovels, start on the outside edge marked with landscape paint and work your way to the middle. Remove the upper layer of sod or plant materials and set it aside to compost. Then remove the soil. If you plan to use the native soil in your mix, move this soil to your amendment pile. Use a ruler to measure the garden depth. If your garden is on a slope, make sure to cut and fill so that the rain garden bed is level (See Slope Handout in Appendix). After the bed is dug out to the correct depth, rototill or double-dig the soil to a depth of 6-12 inches. Then carefully rake the soil to make it level. This will create a transition zone between the native soil and the amended soil. When the rototilling or double-digging is completed, limit foot traffic into the prepared bed to prevent soil compaction. Then add the amended soils.

7) Install Underdrain: If the site has heavy clay soils and drainage is an issue, install an underdrain. An underdrain is a 3-6 inch perforated PVC or black plastic pipe. To install the underdrain, make a channel of pea gravel from the center of the bed to where the underdrain will exit. Make sure that the underdrain slopes 1-3 % away from the garden. Wrap the pipe in a fabric filter or leave it bare. Then lay the underdrain on the pea gravel and cover it with more pea gravel. Then add the amended soil. Another way to install an underdrain is to dig out a deep round hole (like a French drain) in the center of the excavated rain garden and to fill it with gravel. Cover the gravel with a filter fabric and then add the amended soil.

8) Create a Berm: Depending on your garden design, create a full or partial berm around the garden to prevent the runoff from leaving the garden. Berms are usually located on the downstream side of the garden. To create a berm, mound up the native soils to a depth of 4 – 6 inches and tamp the soil down using a Tamp or you can have your students jump on it. Keep adding soil until you have created a compact rounded 4-6 inch lip above the grade of the surrounding land.

9) Amend the Soil: To prepare your amended soil, mix the components together in the proportions chosen. Break up any large clumps. Then use shovels to load the soil into wheel barrels to transport to the rain garden. Dump the soil into the prepared bed and use rakes to smooth it out. Avoid walking in the bed and compacting the soil.

10) Test Drainage: If the rain garden will not be planted the same day as the beds are dug, test the drainage. To test the drainage, use a hose to fill the rain garden so that it is flooded. Record the time. Come back in 24 hours and check to see if the garden is completely drained. If there is standing water, wait a few more days until the soil is drier, remove the soil and add sand to improve the drainage. Then refill the bed and test drainage again. If the garden does not drain in 24 hours, dig out the amended soils and add additional sand or compost to the mix to improve the drainage. Use the information from soil percolation testing in the ***How Deep Will if Flow*** Activity to choose amendments that work with the soil on the school site..

11) Plant Rain Garden Plants: It is a good idea to actually lay out all of the plants in the rain garden bed to see if the layout works. Leave the plants in the center and use popsicle sticks to label where the outer plants go. Start planting in the middle and work your way out. Avoid compacting the amended soil by walking as little as possible in the bed during planting. To plant a potted plant, dig a hole that is 30% wider than the pot and approximately the same depth as the plant in the pot. Remove the plant from the pot. If the plant roots are coiled around in a circle, the plant is pot-bound. Loosen and straighten the roots before putting the plant into the hole. Do not coil the roots in the hole; if you cannot fit the plant in the hole with the roots straight down, dig a deeper hole or cut the roots off. Then center the plant in the hole and add soil to fill in the space between the plant and the hole. As soil is added use fingers to pack it down and repeat until the hole is filled and the top of the root ball is covered. When the plants in the middle are planted, move to the outside edges. If the plan is to label plants, it is best to do this as each plant is planted. Use Popsicle sticks, wire tags, or plant stakes depending on the look desired. Labels are a good idea because they can help with monitoring plant success and teach students and the community plant names.

12) Mulch the Garden: When finished planting all of the plants, mulch the garden. Newspaper makes an excellent weed barrier. Lay down sheets about 4-6 pages thick and overlap the sheets leaving room for the plant to grow. Then add the mulch. Double shredded hardwood mulch works best because it does not float like pine bark and plastic mulches. Approximately 2-3 inches of mulch is needed. Use buckets and pour the mulch between the plants. Then use hands to push the mulch into an even 2-3 inch layer.

13) Water the Garden: It is a good idea to water the rain garden right after you plant it to settle in the plants. Depending upon what time of year you plant the garden, keep an eye on the garden and water it periodically if it becomes dry. After the garden is established the garden should not have to be watered.

14) Maintain the Garden: Rain gardens need to be weeded 2 times a year in the spring and fall. More need to weeding may be at first to allow the rain garden plants to get established. Mulch the garden at least once a year in the fall. If a more formal ornamental-type rain garden was planted, the flowers may need to be dead-headed to promote blooming. Cut plants back after blooming.

Lesson Descriptions:

Option 1: Elementary School

Objectives: Students will:

1) Participate in and/or observe the excavation of the rain garden and preparation of the rain garden bed;
2) Participate in and/or observe the mixing or the rain garden soil and adding it to the rain garden bed;
3) Conduct a drainage test of the rain garden before planting;
4) Layout the plants in the rain garden and properly plant the plants in the garden;
5) Mulch the garden with 3 inches of mulch; and
6) Water the rain garden immediately after planting the garden,/

Topics Covered: Project Planning, Project Implementation, Problem Solving, Teamwork, Garden Construction, Underdrains, Planting Techniques, Mulching Techniques, Garden Maintenance

Activity Time:
1 class period

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

Materials:
Design plan from Put on Your Design Cap
Rain Garden plants
Soil Amendments (top soil, compost, and/or sand – depends on your school site)
Mulch
Pointed shovels
Trowels
Buckets
Wheel barrel (optional)
Hose
Water Source
Gloves
Under drain materials (option 0 depends on your design)

Follow Up
Journals (one per student or team)
Pencils with erasers
Colored markers or crayons
Digital or regular camera (optional)

Extension
None

Introduction: Review the steps in planting the rain garden. Tell the students they are going to be involved primarily with planting the plants. Show students the different plants. Hold up a pot of each plant type. Ask the students if they know which plant it is? If students were assigned a plant to research in the ***Put on Your Design Cap*** Activity that is being used in the rain garden, have that students introduce the plant to the rest of the class. Then plant the garden.

Hands On: Divide the garden into 4 zones and assign 4-6 students and a volunteer to each zone. Allow each student to plant at least one plant. Then have the students help distribute the mulch. Allow students to take turns watering the sections.

Follow-ups: Have the students pick one plant from the rain garden plant (or use the same plant they researched in the ***Put on Your Design Cap*** Activity) and start a journal. . If the students have not researched a plant already, have them conduct research to learn more about the plant. Then observe the plant throughout the seasons through bloom to seed. Have them write their observations in a journal. Have them sketch the plant in its various phases or photograph it for the journal.

Extensions: Have the students share what they learned from observing their plant with the rest of the class.

Option 2/3: Middle School/ High School

Objectives: Students will:

1) Participate in and/or observe the excavation of the rain garden and preparation of the rain garden bed;
2) Participate in and/or observe the mixing or the rain garden soil and adding it to the rain garden bed;
3) Conduct a drainage test of the rain garden before planting;
4) Layout the plants in the rain garden and properly plant the plants in the garden;
5) Mulch the garden with 3 inches of mulch; and
6) Water the rain garden immediately after planting the garden,/

Topics Covered: Problem Solving, Experimental (Rain Garden) Design, Garden Themes, Plant Selection Criteria, Garden Orientation, Design Evaluation Criteria, Modeling, and Oral and Written Presentations

Activity Time:
1-3 class periods

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

Materials:
Design plan from Put on Your Design Cap
Rain Garden plants
Soil Amendments (top soil, compost, and/or sand – depends on your school site)
Mulch
Pointed shovels
Trowels
Buckets
Wheel barrel (optional)
Hose
Water Source
Gloves
Under drain materials (option 0 depends on your design)

Follow Up
Journals (one per student or team)
Pencils with erasers
Colored markers or crayons
Digital or regular camera (optional)

Extension
None

Introduction: Review the steps in planting the rain garden.

Hands On: If possible, involve the students in every phase of the planting event. This will take 3 site visits: 1) sketch out the bed and spray the lines, 2) excavate the bed, install underdrain (optional), mix soil, amend soil, and organize plants for planting day; and 3) plant and water the rain garden.

Follow-up: Observe the rain garden once a week and write their observations in a journal. Note how well the garden drains after a rain, which plants are doing the best and which are not doing well, what weeds are taking up residence in the garden, when the plants go to flower and seed, if the plants have a color change over the season, and what insects, birds, and other animals are visiting the garden.

Extensions: Have students monitor the rain garden (see ***Measuring Up*** Activity).

Lesson 6: Measuring Up

Lesson Overview:

Purpose: This activity will teach students about how to assess their success

Background:
The first rain gardens were installed in the early 1990's in Kansas City, Kansas and Maplewood, Minnesota. They are a type of bio-retention basin. Bio-retention basins are plant filled depressions used to capture runoff and "retain" it until is could soak back into the ground. Most bio-retention basins were filled with either grasses or hardy wetland plants. Rain Gardens are essentially bio-retention basins with attractive garden plants added to make them a landscape feature. Most bio-retention basins were used in commercial applications like adjacent to parking lots, highways, buildings, and roads. The idea of making the bio-retention basins smaller and installing them at residential homes is an innovative approach to managing storm water runoff.

Rain gardens are a relatively new idea and very little research has been done on rain garden effectiveness Preliminary findings indicate that:
1) Plants (particularly native plants) and soils in the rain garden can physically and biologically remove pollutants carried in storm water runoff, particularly dissolved solids and nutrients.
2) Rain gardens reduce storm water runoff volumes by capturing and storing runoff in groundwater aquifers and/or transpiring it back into the atmosphere and this varies by rainfall event, garden size, soil type, and season.
3) Reducing storm water runoff improves streams physical integrity by reducing stream bank erosion and a streams biological integrity by and reducing the negative effects runoff (streambed scouring, dissolved solids, and nutrient loading) has on aquatic macroinvertebrate communities.
4) Rain gardens improve the aesthetics/ wildlife habitat of an area when compared to conventional storm water infrastructure like storm drains, riprap, swales, and diversion ditches.

Because rain gardens are so new, very little is known about what is the best size, shape, soil mix, plants, and water quality/quantity improvements. Monitoring rain gardens is one way to add to the knowledge base and get students engaged in meaningful research that aids water resource professionals and the community. Most rain garden monitoring programs are designed to:measure:
1) the volume of storm water runoff that is diverted from storm water sewers by reducing impervious surfaces;
2) the ability of a rain garden to accept, store, and infiltrate storm water under a variety of conditions (different soil mixes, plant types, seasonal variations, plant maturity, etc.).

Some rain garden monitoring compares rain garden performance to the runoff from various types of impervious materials like roads, parking lots, or semi-pervious materials like pavers and riprap.

There are many aspects of rain gardens that can be measured and here are a few of the many questions being asked:

<u>Hydrology/ Drainage</u>
Is the rain garden able to effectively store at least one inch of rainfall and drain within 24-48 hours? Is the rain garden designed so that water can be released during flood conditions? How much rainfall is trapped in the rain garden and prevented from flowing to nearby streams? What is the appropriate soil mix to encourage water to drain from the rain garden within 24-48 hours? How can heavy clay soils be amended to drain better and not to become water logged? Are underdrains an effective way to manage drainage issues?
Possible studies:
1) Fill the rain garden with water before it is planted and time how fast it drains. Measure the amount of water it took to fill the rain garden. This is pretty easy to do using a garden hose. You have to make sure that the water is discharging from the hose at the same rate. To do this turn the garden hose on and mark how far you turned the knob. Then make sure you set the hose to this mark every time. Start by measuring the amount of time it takes to fill a container of a known volume such as a 10 gallon bucket. Then fill the rain garden without changing the position of the tap supplying the hose. Record amount of time it takes to fill the rain garden and calculate the volume using this formula:

RGV = RGT x BV/ BFT

Where:	RGV	=	Rain garden Volume
	RGT	=	Rain Garden Fill Time
	BV	=	Bucket volume
	BFT	=	Buck Fill Time

For example, if it took 10 seconds for a 10 gallon bucket to fill and it took 20 minutes for the Rain Garden to fill, the rain garden would have a volume of 690 gallons.

$$690 \text{ gallons} = 23 \text{ minutes} \times \frac{60 \text{ seconds}}{1 \text{ minute}} \times \frac{10 \text{ gallons}}{20 \text{ seconds}}$$

Repeat the experiment immediately after the rain garden is planted. Did the rain garden require more or less water to fill? Why? Repeat the experiment at different seasons of the year. Measure the soil moisture to compare how saturated the garden was before you filled it.

2) Create an Isopleth (contour) drawing of your rain garden and then install a stage gauge to determine how much water is being held in the rain garden after various sized rain events. To create an isopleth, draw a sketch of the rain garden to scale on graph paper. Make every square on the graph equal in size. You can choose your own scale. For example each square might equal 3 or 4 inches. Then use a measuring tape and stakes to measure one foot in from the edge of the garden. Repeat the procedure every 2-3 feet until you have gone around the garden at the one foot interval. Use a string or line, a level, and a meter stick like you would for calculating slope (see Slope Handout in Appendices), measure how deep the rain garden depression is at the one foot intervals. For example, it may be 2 inches deep at the 1 foot interval. Record this information on your map. Then repeat the exercise at the 2 foot interval, 3 foot interval and so on until the entire garden is mapped. Your drawing will look sort of like a topographic map. Make sure to pound in one yellow tent stake at every interval in a line. You will use these markings and your stage gauge later on to determine fill volumes after rain events. Then calculate the volume of the garden at various stages: To do this, count all of the full squares and multiple by the area of each square. For example, if each square is 4 inches by 4 inches or 16 square inches and the stage height is 4 inches, multiply 16 times 4 to get 64 square inches. Then multiple this times the number of squares. When you are finished convert the measurement to cubic feet. Then pound a metal or wooden stake into the garden and mark it with the stage heights. After a rain event, find out how many inches of rain fell in your location using local weather data or a rain gauge installed by your garden (see Resources). Then measure the stage height of water and measure where the water rose up to using the yellow garden stakes. Mark this on your isopleths and calculate the volume of water. This is the volume of water your rain garden captured after one rain event. To find out how much rain it could divert from the storm sewers in a year, use your data on how much fell during a specific event, say a 1 inch rain fall and use the average rainfall for the year to determine the volume in one year.
3) Observe the garden immediately after a rain event. Photograph it. Then visit the garden at regular intervals over a 24-48 hour period and photograph the rain garden. Observe how the garden drains. Where is the water standing? Continue the experiment after 48 hours taking soil moisture readings at selected locations. Are some areas of the garden retaining water longer? Why? Is that affecting plant success?
4) Experiment with the underdrain. Leave the underdrain open and see how this affects drainage. Observe the underdrain outfall. How much water is leaving the rain garden? Did leaving the underdrain open dry out the garden sooner? Compare the closed underdrain results with the open underdrain results.

<u>Plant Success</u>

What are the best plants to use in a rain garden? Do natives work better than ornamental varieties? Which plants perform well and which ones do not. Do some plants perform better in different zones of the rain garden – the wet, dry, or intermediate zones? Are some plants more invasive than others and crow out other species? What types of plants work best herbaceous, grasses, shrubs, over even trees?

Possible studies:

1) Assign a specific student to study one type of plant. Have them observe the plant over time including measuring soil moisture and soil fertility. If the same plant occurs in several areas, is it doing better in one place? Why?
2) Are natives doing better than non-natives?
3) What size plants were planted – if the plants were different sizes, which ones are doing better?

4) Which plants are growing the best?
5) Are any plants invasive (taking over the garden)? What are the types of weeds that are invading the garden?
6) Which plants do better in what conditions? You can use an inexpensive soil moisture, pH, and nutrient probe to evaluate the soil conditions each plant is growing in. (See Resources) To see how the rain garden is affecting the plants, monitor the garden starting immediately after the surface water drains after a rain event and continue daily until the garden is dried out. Where is the moisture being retained in the garden? And how is this affecting the plants? Are there differences in pH in wetter versus drier areas? Are the nutrients more concentrated in particular sections of the garden and why? How might this be affecting plant success? Compare what the plant guides say about plants and the conditions they thrive in. Are your plants behaving the way experts think they should?

Water Quality Improvements:
Runoff typically flows untreated over pavement into storm drains and empties into streams. Are rain gardens effective at removing pollutants? What types of pollutant do they remove? Sediment and nutrients by volume constitute two major water quality issues – do rain gardens remove these types of pollutants? What other pollutants can they remove – Oil and gasoline? Pesticides? Bacteria? Rain garden studies have shown that rain gardens can be effective at removing total dissolved solids, nitrates, phosphates, and organic contaminants like oil and gasoline.
Possible studies:
1) Determine where the water is flowing into the garden (inlet) and where it is flowing out (outlet). If the garden has an underdrain system with ports, this is easy! If not, create a way to collect water by digging a hole and installing a plastic container level with the soil at the inlet and outlet. To see if the rain garden is filtering out pollutants, install a capped 2-3 inch PVC tube with holes drilled in the sides so it goes down about 2-3 feet In the center of the garden,.
2) Then monitor the garden after rain events and perform water quality tests on the inlet water and the outlet water. Use a hand pump and plastic tubing to pump out the water and test it. Brake bleeding kits found at the automotive store contain inexpensive hand pumps, tubing, and some even come with receptacles that can be used to collect the water samples. (See Resources).
3) You can monitor these parameters using an inexpensive TDS Meter and water test strips or single parameter test kits. (See Resources)
4) Were there any changes in water quality? Compare the results with the same tests performed on the inlet? Was there a difference in water quality?
5) Continue testing over time. Do rain gardens remove pollutants in winter when the plants are dormant? As the Rain Garden matures, is it more effective at removing pollutants?

Wildlife Habitat:
Do rain gardens improve habitat for bees, butterflies, birds, and other wildlife? Can rain gardens be designed to provide food for wildlife? Humans?
Possible studies:
1) Conduct an ongoing observational monitoring and record how many and what type of wildlife is using the garden. Be sure to include animal tracks too. Record what plants the animals are using? Why?
2) If the garden has an edible component, what animals are eating what?
3) Are any of the animals visiting the garden harming the garden and how? Deer, rabbits, insects?

Learning Labs
Can rain gardens be designed to serve as a learning lab that supports the curricula?
Possible studies:
1) Take a survey to see what kind of possible uses other classes at the school might have for the garden before the garden is designed and take a survey after to see who is using the garden for what?
2) Find out what other classes are using the garden and take a survey to see how they are using it including how often and what types of activities they are doing. Ask if there are modifications that can be made to make the rain garden more useful and implement the suggestions if possible, Then take another survey to see if it is being used more and for what purposes.

Developing hypotheses, designing experiments, and conducting ongoing long term studies are all part of the curricula. Monitoring rain gardens can add to our baseline knowledge and provide students will opportunities to engage in meaningful research at the same time.

Lesson Descriptions:

<u>Option 1: Elementary School</u>

Objectives: Students will:

1) Make a photographic record of their rain garden to show how the garden matured;
2) Observe the plants and make notes on how each of the plant species is performing over time;
3) Observe and record invasive plant species that enter the garden and weed the garden to remove them;
4) Observe and record use of the rain garden by birds, butterflies, bees (and other pollinators), and other wildlife;
5) Record rain gauge reading after storm events, photograph the rain garden after a storm event, and record how long it took for the rain garden to drain in a log book;
6) Compare nutrient levels and turbidity in untreated runoff to water that has infiltrated through the rain garden; and
7) Observe how soil moisture varies throughout the garden using a soil probe and compare soil moisture levels over time after a rain event.

Topics Covered: Precipitation, Rain Gauges, Plant and Animal Identification, Plant Succession, Invasive Species; Observation and Record Keeping, Water Quality Monitoring, Soil Moisture Monitoring, Data Interpretation, and Oral/Written Presentations

Activity Time:
1 or more class periods

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

Materials:
Rain gauge
Digital or regular Camera
Identification Guides to local plants and animal species including weeds, insects, birds, reptiles, amphibians, and mammals
Measuring Up Butcher Paper Example Plant Success Record
Pencils with erasers
Notebook paper
Clip board

Follow Up:
Rain Gauge
Meter stick
Large juice can (64 oz with top removed)
Panty hose
Scissors
Large heavy duty rubber bands
Test tab or test strip monitoring kit that measures nitrates, phosphates, and turbidity
Hand pump to remove treated runoff from underdrain port
Clean dry sample containers with lids
Pencils with erasers
Notebook paper
Clip board

Extension:
Access to computer
Reference materials on themed gardens

Introduction:

Review with the students why the rain garden was planted. Ask the students to think of ways they could measure whether or not the rain garden project has been a success. List these measures on the board. Possible answers might be that it captured the rain and did not allow it to run off into the storm drain or the plants are alive and doing well. Ask the students to describe ways they could monitor the garden to determine how successful the garden is at diverting rain from storm drains in a 24-48 hour time period. First talk about how they could figure out how much water the rain garden is removing using their rain gauge, the drainage area, and the size of the garden? Ask them when is the best time to monitor the garden and how often should they do it? Have the students develop a plan to monitor the rainfall and runoff volumes.

Next discuss ways they could monitor plant success. Review the plants you planted in the garden and where each is planted. Ask the students what they think is going to happen in the garden over time? Possible answers might be that some plants get bigger, some plants die, weeds start growing, etc. Then ask the students to list ways they could monitor the plants. Then have the students develop a plan to monitor the plants. What would be the best tools to use? How often and when should they monitor the garden? Can they monitor at the same time they are monitoring runoff? Why or why not?

Hands On:

1) Install a rain gauge by the rain garden. After each rain event have the students visit the rain garden and record the rain fall amount from the rain gauge and then have the students take a picture. Then empty the rain gauge and put back in the same spot. Then come back after 24 hours and take another picture. Did the garden drain completely? If not, return the next day and take another picture. Did the rain garden drain after the second day?
2) Have students take a picture of the garden right after it is planted. Have them make a sketch of where each plant is located. Then have them photograph the garden once a week or once every two weeks and compare the photos. What is happening? Are all the plants doing well? Why or why not? Make a scrap book of the rain garden progress. Starting with the planting day, take a picture of the garden and put it into the scrap book along with some observation. Once every 2 weeks, photograph the garden and add it to the photo album. Then after each rain event, record how much rain fell and take a picture of the garden. Add this photo and observations to the scrap book.
3) Make a list of the plants in the rain garden and put it on the butcher paper. Each week look at the plants and assess the plants condition: healthy and growing, no change, declining, or dead. Take a photo of that plant and put it into the table on the butcher paper (see Measuring Up Butcher Paper Example Plant Success Record in Appendix).
4) Observe the use of the rain garden by birds, butterflies, bees (and other pollinators), and other wildlife. Take pictures and use identification guides to identify each one. Count the numbers and types and make a list of who is visiting the garden. Which plants are the animals most attracted to and why? If you could re-design your garden to be more beneficial to wildlife what plants would you choose?
5) Identify any plants that start growing in your garden that you did not plant. Photograph each one and use a plant identification guides to identify each one. Count the number and types of weeds that start growing in your rain garden. Then remove the weeds. Which weeds were the most prevalent? Research what you could do to reduce invasive weed species. What methods would reduce weeds and be safe for the environment?
6) When the monitoring program is complete, discuss your findings. Is the rain garden draining within 24-48 hours? Are all of the plants surviving? If not, which ones are not doing well? Have them research gardening books to see if they can determine why? What weeds invaded the garden? Were they a significant problem? If so, how could you control them? What wildlife visited the garden and which plants did they visit?
7) Have the students write up their findings. Then contact your local stormwater district office and share your results.

Follow-ups:

1) Determine how much rain if falling on the rain garden each week and each month using the rain gauge readings. Is the rainfall amount above normal, normal, or below normal? Using the rain garden volume amount from the Capture, Store, and Release Activity, Calculate how much runoff has been captured in the rain garden.
2) Use a hand pump to remove water from the underdrain if your rain garden has one. If it does not, bury a large juice can (64 oz) with the top removed and covered with a nylon stocking secured by a large rubber band so the top of the can is 3-4 inches below the top of the garden and mark the can with a yellow tent stake or some other visible marker. During or after a rain event, collect water that is running off and adjacent impervious area like a parking lot or road into the storm drain and test this sample for the water using your water monitoring kit for nutrients (nitrates and phosphates) and turbidity. After the runoff has soaked into the rain garden, remove the can and test the water using your water monitoring kit for nutrients (nitrates and phosphates) and turbidity. Compare the untreated water to the treated water. Did the rain garden remove nutrients and turbidity? Vary your experiment by burying several cans in the garden and testing different types of impervious areas. You might also compare the garden in different seasons to see what effect the plants have on reducing pollutants.

Extension: If this rain garden has a theme, such as Butterfly Garden, observe and record what butterfly species are visiting the garden and what plant(s) they are using. Research the life cycles of butterflies students would like to attract to the garden and make a plan for attracting even more butterflies to the garden. If students have selected another theme like attracting wildlife, have them observe the wildlife to see how they are using the garden. Then research what wildlife and make a plan to attract even more wildlife.

Option 2/3: Middle School/ High School

Objectives: Students will:

1) Evaluate the success of their rain garden project by selecting a monitoring topic, developing a hypothesis, and conducting a rain garden monitoring study.

Topics Covered: Precipitation, Rain Gauges, Plant and Animal Identification, Plant Succession, Invasive Species; Observation and Record Keeping, Water Quality Monitoring, Soil Moisture Monitoring, Data Interpetation, and Oral/Written Presentations

Activity Time:

Multiple class periods depending on study design.

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

Materials:

Depends on projects students choose (see Background for possible studies)
Digital Camera
Pencils with erasers
Notebook paper
Clip board
Meter stick
25 foot line
Line Level
Tent Stakes
Rain Gauge
Soil Moisture/pH/nutrient Probe
Multi-parameter Water Test Kit
Hand pump to remove treated runoff from underdrain port
Clean dry sample containers with lids

Introduction: Discuss how to determine if the garden is a success and develop a list of success measures. (captures all the runoff after rain event, plants are growing and doing well, water quality is improved, and garden is fulfilling its secondary purpose). Then develop a hypothesis and design a monitoring plan to measure your success. For example, you may want to measure the success of the design. A hypothesis might be that the Rain Garden will successfully capture 1 inch of rainfall and drain within 24 hours. Design an experiment to achieve this goal. Measure the success of various plant species. In that case, the hypothesis might be that Black-eyed Susan's are the hardiest plants in the rain garden and will out perform other species. Then design you experiment to measure this. Or another hypothesis is that rain gardens will improve water quality by removing 50% of the sediment from runoff. Design an experiment to prove this. Have students select a hypothesis they are interested in.

Hands On:

1) Ask students how they would measure the success of their rain garden project. Develop different hypotheses and write them on the board. Ask students that they are going to pick 4 hypotheses for the class to monitor. Tell each student they can vote 3 times by raising their hands. Go though list and vote. The top 4 vote getters are the hypotheses the class will test.
2) Divide the class into 4 teams and assign one hypotheses to each team. Have each team develop a study design to measure their hypotheses.
   a) For example, if they want to monitor whether the rain garden is successfully capturing and draining 1 inch of rainfall, how would they do that? Install a rain gauge. Develop a plan to monitor the weather for rainfall. Set up plan to monitor how quickly the rain garden drains. Use a soil moisture probe to monitor the rain garden in dry conditions, immediately post rain event, and over the next 48 hours. They could use their soil moisture information to show the runoff is either percolating into the groundwater or evaporating/transpiring back into the atmosphere.
   b) If they chose the plant success option, they could set up an experiment to observe a certain number of Black-eyed Susan's and compare them to one or more other plants. They might measure height, spread, number of blooms, seed production. You might also look at factors affecting the plant success such as soil moisture, soil fertility, and sun exposure.
   c) If you are doing the water quality experiment, have them figure out where they could collect untreated runoff that they could compare with the treated runoff. They would also need to figure out a way to capture runoff that has filtered through the garden. Then they could figure out ways to measure sediment removal such as total solids tests, total dissolved solids meters, or turbidity measurements.
   d) Or the students could select other measures and design their studies.
3) Have the students conduct their research over a period of time the teacher determines and then present their findings to the rest of the class. Is the rain garden successful? Why or why not?

Follow-ups:
1) Have the students evaluate their studies. Did they select a hypothesis they could measure? What were the sources of error? How did they try to reduce the sources for error? What would they have done differently if they were allowed to repeat the study? Based on what they found out, what would they hypothesis next?
2) Have the students share the results of their monitoring plan with Water Resources Professionals.

Extensions:
1) Design a routine monitoring program students could put into place to evaluate the long-term success of the rain garden project.
2) Invite a water resource professional to the class to evaluate the monitoring plans and to provide feedback to the students. Based on this input revise the monitoring plans.
3) Have students select several parameters to monitor on an ongoing basis and have them monitoring the rain garden throughout the school year.

Rain Garden Lesson Guide Correlations by Grade

Grade Level	Study Area	Benchmark	Performance Indicator	No Place to Run	Capture, Store, and Release	How Deep Will It Flow	Put on Your Design Cap	Get Down and Dirty	Measuring Up
3	Earth and Space Sciences	C: Describe Earth's resources including rocks, soil, water, air, animals, and plants and the ways in which they can be conserved.	C4. Observe and describe the composition of soil (e.g. small pieces of rock and decomposed pieces of plants and animals and the products of plants and animals)			X			
3	Earth and Space Sciences	C: Describe Earth's resources including rocks, soil, water, air, animals, and plants and the ways in which they can be conserved.	C5. Investigate the properties of soil (e.g. color, texture, capacity to retain water, and ability to support plant growth).	X	X	x			X
3	Earth and Space Sciences	C: Describe Earth's resources including rocks, soil, water, air, animals, and plants and the ways in which they can be conserved.	C6.Investigate that soil is often found in layers and can be different from place to place.			X			
3	Life Sciences	C: Compare changes in an organism's ecosystem/ habitat that affect survival.	C6. Describe how changes in an organism's habitat are sometimes beneficial and sometimes harmful.						X
3	Science and Technology	A: Describe how technology affects humans.	A2. Describe ways that using technology can have helpful and/or harmful results.					X	X
3	Science and Technology	B. Describe and illustrate the design process.	B4. Use a simple design process to solve a problem (e.g. identify the problem, identify possible solutions, and design a solution).	X	X		X		
3	Scientific Inquiry	A: Use appropriate instruments safely to observe, measure, and collect data when conducting scientific investigations.	A1. Select the appropriate tools and use relevant procedures to measure and record length and weight using metric and English measurements,	X	X				X
3	Scientific Inquiry	B. Organize and evaluate observations, measurements, and other data to formulate references and conclusions.	B5. Record and organize observations (e.g. journals, charts, and tables)	X	X	X	X		X
3	Scientific Inquiry	C: Develop, design, and safely conduct scientific investigations and communicate the results.	C6. Communicate scientific findings to others using a variety of methods (e.g. pictures, written, oral, and recorded observations.)	X	X		X		X
3	Scientific Ways of Knowing	B: Describe different types of investigations and use results and data from the investigations to provide evidence to	B1. Describe different kinds of investigations that scientists use depending on the questions they are trying to answer.						X

		support explanations and conclusions.							
3	Scientific Ways of Knowing	C: Explain the importance of keeping records of observations that are accurate and understandable.	C2. Keep records of investigations and observations and do not change records that are different from someone else's work.	X	X	X	X		X
4	Earth and Space Sciences	D. Analyze weather and changes that occur over a period of time.	D4. Describe weather by measurable quantities such as temperature, wind direction, precipitation, and barometric pressure	X	XX				X
4	Earth and Space Sciences	D. Analyze weather and changes that occur over a period of time.	D5. Record local weather information on a calendar or map and describe changes over a period of time (e.g. barometric pressure, temperature, precipitation symbols, and cloud conditions)						X
4	Life Sciences	B: Analyze plant and animal structures and functions needed for survival and describe flow of energy through a system that all organisms use to survive.	B2. Relate plant structures to their specific functions (e.g. growth, survival, and reproductions)				X		X
4	Science and Technology	B. Describe and illustrate the design process.	B5. Describe, illustrate, and evaluate the design process to solve a problem.	X	X		X		X
4	Scientific Inquiry	A. Use appropriate instruments safely to observe, measure, and collect data when conducting scientific investigations.	A1. Select the appropriate tools and use relevant procedures to measure and record length, weight, volume, temperature, and area using metric and English measurements	X	X				C
4	Scientific Inquiry	C: Develop, design, and safely conduct scientific investigations and communicate the results.	C3. Develop, design, and conduct safe, simple investigations or experiments to answer questions.	X	X				C
4	Scientific Ways of Knowing	C: Explain the importance of keeping records of observations that are accurate and understandable.	C2. Record the results and data from an investigation and make a reasonable explanation.	X	X	X	X		X
4	Scientific Ways of Knowing	C: Explain the importance of keeping records of observations that are accurate and understandable.	C3. Explain discrepancies in an investigation using evidence to support findings.	X	X				X
4	Scientific Ways of Knowing	C: Explain the importance of keeping records of observations that are accurate and understandable.	C4. Explain why keeping records or observations and investigations are important.	X	X				

5	Earth and Space Sciences	C: Describe Earth's resources including rocks, soil, water, air, animals, and plants and the ways in which they can be conserved.	C6. Investigate ways Earth's renewable resources (e.g. fresh water, wildlife, and trees) can be maintained.				X		
5	Life Sciences	C: Compare changes in an organism's ecosystem/ habitat that affect survival.	C6. Analyze how all organisms, including humans, cause changes in their ecosystems and how these changes can be beneficial, neutral, or detrimental.	X	X		X		X
5	Science and Technology	A: Describe how technology affects humans.	A1. Investigate positive and negative impacts of human activity and technology on the environment.						X
5	Science and Technology	B. Describe and illustrate the design process.	B3. Explain how the solution to one problem may create other problems.						X
5	Scientific Inquiry	A: Use appropriate instruments safely to observe, measure, and collect data when conducting scientific investigations.	A1. Select and safely use the appropriate tools to collect data when conducting investigations and communicating findings to others (e.g. thermometers, timers, balances, spring scales, magnifiers, microscopes, and other appropriate tools.)	X	X			X	X
5	Scientific Inquiry	B. Organize and evaluate observations, measurements, and other data to formulate references and conclusions'.	B3. Use evidence and observations to explain and communicate the results of investigations.	X	X	X	X		X
5	Scientific Inquiry	B. Organize and evaluate observations, measurements, and other data to formulate references and conclusions.	B6. Explain why the results of an experiment are sometimes different.	X	X	X			X
5	Scientific Ways of Knowing	A: Distinguish between fact and opinions and explain how ideas and conclusions change as new knowledge is gained.	A3. Explain why an experiment must be repeated by different people or at different times or places and yield consistent results before the results are accepted.			X			X
5	Scientific Ways of Knowing	C: Explain the importance of keeping records of observations that are accurate and understandable.	C5. Keep records of investigations and observations that are understandable weeks or months later.					X	X
5	Earth and Space Sciences	D: Identify that the lithosphere contains rocks and minerals and that minerals make up rocks. Describe how rocks and minerals are	D1: Describe the rock cycle and explain that there are sedimentary, igneous, and metamorphic rocks that have distinct properties (e.g. color, texture,) and are formed in			X			

		formed and/or classified.	different ways.						
6	Life Sciences	D. Explain how extinction of a species occurs when the environment changes and its adaptive characteristics are insufficient to allow survival (as seen in evidence of the fossil record).	D8. Describe how organisms interact with one another.				X		X
6	Science and Technolo gy	A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.	A1. Explain how technology influences the quality of life.					X	
6	Science and Technolo gy	A: Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.	A2. Explain how decisions about the use of products and systems can result in desirable or undesirable consequences (e.g. social and environmental)	X				X	X
6	Science and Technolo gy	B. Design a solution or product taking into account needs and constraints (e.g. costs, time, trade-offs properties of materials, safety and aesthetics).	B5. Design and build a product or create a solution to a problem given one constraint.				X	X	
6	Scientific Inquiry	A. Explain that there are differing sets of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations, and appropriate tools.	A1. Explain that there are not fixed procedures for guiding a scientific investigations, however the nature of the investigation determines procedures needed.		X				X
6	Scientific Inquiry	A. Explain that there are differing sets of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations, and appropriate tools.	A2. Choose the appropriate tools or instruments and use relevant safety procedures to complete scientific investigations.	X		X			X
6	Scientific Ways of Knowing	A. Use skills of scientific inquiry processes (e.g., hypothesis, record keeping, description and explanation.)	A1. Identify that hypotheses are valuable event when they are not supported.				X		X
6	Scientific Ways of Knowing	B. Explain that importance of reproducibility and reduction of bias in scientific methods.	B2. Describe why it is important to keep clear, thorough, and accurate records.						X

7	Earth and Space Sciences	C. Describe how the interactions of mater and energy throughout the lithosphere, hydrosphere, and atmosphere (e.g. water cycle, weather, and pollutions).	C2. Explain that Earth's capacity to absorb and recycle materials naturally can change environmental quality depending on the length of time involved.	X	X	X			
7	Earth and Space Sciences	C. Describe how the interactions of mater and energy throughout the lithosphere, hydrosphere, and atmosphere (e.g. water cycle, weather, and pollutions).	C4. Describe how rivers, lakes, and groundwater can be depleted or polluted becoming less hospitable or unsuitable for life.	X					
7	Earth and Space Sciences	C. Describe how the interactions of mater and energy throughout the lithosphere, hydrosphere, and atmosphere (e.g. water cycle, weather, and pollutions).	C7. Read weather maps to interpret local, regional, and national weather.		X				X
7	Earth and Space Sciences	C. Describe how the interactions of mater and energy throughout the lithosphere, hydrosphere, and atmosphere (e.g. water cycle, weather, and pollutions).	C9. Describe the connection between the water cycle and weather related phenomena (floods).	X	X				X
7	Science and Technology	A. Give examples of how technological advances influences by scientific knowledge alter the quality of life.	A1. Explain how needs, attitudes, and values influence the direction of technological developments in various cultures.			X			X
7	Science and Technology	B. Design a solution or product taking into account needs and constraints.	B4. Design and build a product or create a solution to a problem given two constraints.				X	X	
7	Scientific Inquiry	A. Explain that there are differing set of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations, and appropriate tools.	A1. Explain that variables and controls can affect the results of an investigation and that ideally one variable should be tested at a time; however that is not always possible.		X	X			X
7	Scientific Inquiry	A. Explain that there are differing set of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations, and	A4. Choose the appropriate tools or instruments and use relevant safety procedures to complete scientific investigations.		X	X			X

		appropriate tools.							
7	Scientific Ways of Knowing	B. Explain the importance of reproducibility and reduction of bias in scientific methods.	B3. Describe how the work of science requires a variety of human abilities and qualities that are helpful in daily life (e.g. reasoning, creativity, skepticism, and openness)	X			X	X	X
8	Earth and Space Sciences	C. Describe how the interactions of mater and energy throughout the lithosphere, hydrosphere, and atmosphere (e.g. water cycle, weather, and pollutions).	C11. Use models to analyze the size and shape of the earth, its surface and its interior (e.g. globes, topographic maps, and satellite images	X		X	X		
8	Life Sciences	D. Explain how extinction of a species occurs when the environment changes and its adaptive characteristics are insufficient to allow survival (as seen in evidence of the fossil record).	D3. Explain how variations in structure, behavior, or physiology allow some organisms to enhance their reproductive success and survival in a particular environment						X
8	Science and Technology	A. Give examples of how technological advances influences by scientific knowledge alter the quality of life.	A2. Examine how choices regarding the use of technology are influenced by the constraints caused by various unavoidable factors (e.g. geographic location, limited recourses, social, political, and economic considerations)	X		X	X		
8	Science and Technology	B. Design a solution or product taking into account needs and constraints.	A3: Design and build a product or create a solution to a problem given more than two constraints (Grade 8)				X	X	
8	Science and Technology	B. Design a solution or product taking into account needs and constraints.	A4. Evaluate the overall effectiveness of a product design or solution						X
8	Scientific Inquiry	A. Explain that there are differing set of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations, and appropriate tools.	A1. Choose appropriate tools or instruments and use relevant safety procedure to complete scientific investigations		X	X			X
8	Scientific Inquiry	B. Analyze and interpret data from scientific investigations using appropriate mathematical skills in order to draw valid conclusions.	B3. Read, construct and interpret data in various forms produced by self and other in both oral and written form		X	X			X

8	Scientific Ways of Knowing	A. Use skills of the scientific inquiry process.	A1. Identify the difference between a description and an explanation.						X
8	Scientific Ways of Knowing	B. Explain the importance of reproducibility and reduction of bias in scientific methods.	B2. Explain why I is important to examine data objectively and not let bias affect observations.				X		X
9	Earth and Space Sciences	F: Summarize the historical development of scientific theories and ideas and describe emerging issues in the study of Earth and Space sciences.	F8: Use historical examples to explain how new Ideas are limited by the context in which they are conceived; are often initially rejected by the scientific establishment; sometimes spring from unexpected findings and usually grow slowly through contributions from many different investigators (e.g. heliocentric theory and plate tectonics theory).						X
9	Physical Sciences	C: Describe the identifiable physical properties of substances (e.g. color, hardness, conductivity, density, concentration, and ductibility). Explain how changes in these properties can occur without changing the chemical nature of the substance.	C9: Investigate the properties of pure substances and mixtures (e.g. density, conductivity, hardness, properties of alloys, superconductors, and semiconductors).				X		X
9	Science and Technolo gy	A: Explain the ways in which the processes of technological design respond to the needs of society.	A2: Identify a Problem or need, propose designs and choose among alternative solutions for the problem.	X		X	X		
9	Science and Technolo gy	A: Explain the ways in which the processes of technological design respond to the needs of society.	A3: Explain why a design should be continually assessed and the ideas of the design should be tested, adapted, and refined.	X		X			
8	Science and Technolo gy	B: Explain that science and technologies are interdependent; each drives the other.	B1: Describe means of comparing the benefits with the risks of technology and how science can inform public policy.						X
9	Scientific Inquiry	A: Participate in and apply the process of scientific investigation to create models and to design, conduct, evaluate, and communicate the results of these investigations.	A1: Distinguish between observations and inferences given a scientific situation.						X
9	Scientific Inquiry	A: Participate in and apply the process of scientific investigation to	A2: Research and apply appropriate safety precautions when designing and conducting						X

		create models and to design, conduct, evaluate, and communicate the results of these investigations	scientific investigations (e.g. OSHA, Material Safety Datasheets (MSDS).						
9	Scientific Inquiry	A: Participate in and apply the process of scientific investigation to create models and to design, conduct, evaluate, and communicate the results of these investigations	A4: Decide what degree of precision based on the data is adequate and round off the results of calculator operations to the proper number of significant figures to reasonably reflect those inputs.		X	X			X
9	Scientific Inquiry	A: Participate in and apply the process of scientific investigation to create models and to design, conduct, evaluate, and communicate the results of these investigations	A5: Develop oral and written presentations using clear language, accurate data, appropriate graphs, tables, maps, and available technology.	X		X			X
9	Scientific Inquiry	A: Participate in and apply the process of scientific investigation to create models and to design, conduct, evaluate, and communicate the results of these investigations	A6: Draw logical conclusions based on scientific knowledge and evidence from investigations.	X	X	X	X		X
9	Scientific Ways of Knowing	A; Explain the scientific knowledge must be based on evidence, be predictive, logical, subject of modification and limited to the natural world.	A3: Demonstrate that reliable scientific evidence improves the ability of scientists to offer accurate predictions.		X				X
9	Scientific Ways of Knowing	B: Explain how scientific inquiry is guided by knowledge, observations, ideas, and questions.	B6: Explain that inquiry fuels observation and experimentation that produce data that are the foundation of scientific disciplines. Theories are explanations of these data.						X
9	Scientific Ways of Knowing	B: Explain how scientific inquiry is guided by knowledge, observations, ideas, and questions.	B7: Recognize that scientific knowledge and explanations have changed over time; almost always building on earlier knowledge.						X
9	Scientific Ways of Knowing	C: Describe ethical practices in science (e.g. individual observations and confirmations, accurate reporting, peer review and publication) are required to reduce bias.	C2:			X			X

9	Scientific Ways of Knowing	D: Recognize that scientific literacy is a part of being a knowledgeable citizen.	D8: Illustrate that much can be learned about the internal workings of science and the nature of science from the study of scientists, their daily work, and their efforts to advance scientific knowledge in their area of study.						X
9	Scientific Ways of Knowing	D: Recognize that scientific literacy is a part of being a knowledgeable citizen.	D9: Investigate how the knowledge, skills, and interests learned in the science classes apply to the careers students plan to pursue.		X	X			
10	Earth and Space Sciences	D: Describe the finite nature of Earth's resources and those human activities that can conserve of deplete Earth's resources.	D5: Explain how the acquisition and use of resources, urban growth, and waste disposal can accelerate natural change and quality of life.						X
10	Earth and Space Sciences	D: Describe the finite nature of Earth's resources and those human activities that can conserve of deplete Earth's resources.	D6: Describe ways that human activity can alter biochemical cycles (e.g. carbon and nitrogen cycles) as well as food webs and energy pyramids (e.g. pest control, legume rotation of crops vs. chemical fertilizers).	X					X
10	Life Sciences	F: Explain the structure and function of ecosystems and relate how ecosystems change over time.	F15: Explain how living things interact with biotic and abiotic components of the environment (e.g. predation, completion, natural disasters and weather.				X		X
10	Life Sciences	F: Explain the structure and function of ecosystems and relate how ecosystems change over time.	F16: Relate how distribution and abundance of organisms are limited by the ability of the ecosystem to recycle materials and the availability of matter, space and energy.				X		X
10	Life Sciences	G: Describe how human activities can impact the status of natural systems.	G18: Describe ways that human activities can deliberately or inadvertently alter the equilibrium in ecosystems. Explain how changes in technology/biotechnology can cause significant changes either positive or native, in environmental quality and carrying capacity.	X			X		X
10	Life Sciences	G: Describe how human activities can impact the status of natural systems.	G19: Illustrate how uses of resources at locate, state, regional, national, and global levels have affected the quality of life (e.g. energy production and sustainable vs. nonsustainable agriculture.					X	

10	Science and Technolo gy	A: Explain the ways in which the processes of technological design respond to the needs of society.	A3: Explain that when evaluating a design for a device or process, thought should be given to how it will be manufactured, operated, maintained, replaces, and disposed of in addition to who will sell, operate, and take care of it. Explain how the cost associated with these considerations may introduce additional constraints on the design.	X	X		X		X
10	Science and Technolo gy	B: Explain that science and technologies are interdependent; each drives the other.	B1: Cite examples of ways that scientific inquiry is driven by the desire to understand the natural world and how technology is driven by the need to meet human needs and solve problems.			X	X		
10	Science and Technolo gy	B: Explain that science and technologies are interdependent; each drives the other.	B2: Describe examples of scientific advances and emerging technologies and how they may impact society.				X		
10	Science Inquiry	A. Participate in and apply the processes of scientific investigation to create models and to design, construct, evaluate and communicate the results of these investigations.	A2: Present scientific findings using clear language, accurate data, appropriate graphs, tables, maps, and available technology	X	X	X			X
10	Science Inquiry	A. Participate in and apply the processes of scientific investigation to create models and to design, construct, evaluate and communicate the results of these investigations.	A3: Use mathematical modals to predict and analyze phenomena.	X	X	X	X		X
10	Science Inquiry	A. Participate in and apply the processes of scientific investigation to create models and to design, construct, evaluate and communicate the results of these investigations.	A4: Draw conclusions from inquiries based on scientific principals, the use of logic and evidence (data) from investigations.	X	X	X	X		X
10	Scientific Ways of Knowing	D: Recognize that scientific literacy is a part of being a knowledgeable citizen.	D7: Investigate how the knowledge, skills, and interests learned in the science classes apply to the careers students plan to pursue.				X		
11	Earth and Space Sciences	B: Describe how Earth is made up of a series of interconnected systems and how a change in one system affects other	B3: Explain heat and energy transfers in and out of the atmosphere and its involvement in weather and climate (radiation, conduction, convection, and advection).						X

		systems.							
11	Earth and Space Sciences	C: Explain that humans are an integral part of the Earth's system and the choices humans make today impact natural systems in the future.	C9: Explain the effects biomass and human activities have on climate (e.g. clean change and global warming).			X			X
11	Earth and Space Sciences	C: Explain that humans are an integral part of the Earth's system and the choices humans make today impact natural systems in the future.	C11: Analyze how materials from human societies (e.g. radioactive waste and air pollution) affect both physical and chemical cycles of Earth.						X
11	Earth and Space Sciences	C: Explain that humans are an integral part of the Earth's system and the choices humans make today impact natural systems in the future.	C12: Explain ways in which humans have had a major effect on other species (e.g. the influence of humans on other organisms through land use which decreases the space available to other species and pollution which changes the chemical composition of air, soil, and water.				X		X
11	Earth and Space Sciences	C: Explain that humans are an integral part of the Earth's system and the choices humans make today impact natural systems in the future.	C13: Explain how human behavior affects the basic processes of natural ecosystems and the quality of the atmosphere, hydrosphere, and lithosphere.	X			X		X
11	Life Sciences	A: Describe how processes at the cellular level affect the functions and characteristics of an organism.	A1: Describe how the maintenance of a relatively stable internal environment is required for the continuation of life, and explain how stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of pathogens.			X	X		X
11	Life Sciences	B: Explain how humans are connected to and impact natural systems.	B5: Investigate the impact on the structure and stability of ecosystems due to changes in their biotic and abiotic components as a result of human activity.	X			X		X
11	Life Sciences	F: Explain how human choices today will affect the quality and quantity of life on earth.	F9: Give examples of how human activity can accelerate rates of natural changes and can have unforeseen consequences.				X		X
11	Life Sciences	F: Explain how human choices today will affect the quality and quantity of life on earth.	F11: Investigate issues of environmental quality at local, regional, national, and global levels such as population growth, resource use, population distribution, over	X			X		

			consumption, the capacity of technology to solve problems, poverty, the role of economics, politics, and different ways humans view the earth.						
11	Science and Technolo gy	A: Predict how human choices today will determine the quality and quantity of life on earth.	A1: Identify that science and technology are essential social enterprises but alone they can only indicate what can happen, not what should happen. Realize the latter involves human decisions about the use of knowledge.				X		
11	Science and Technolo gy	A: Predict how human choices today will determine the quality and quantity of life on earth.	A2: Predict how decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment and/or humans.	X					
11	Science and Technolo gy	A: Predict how human choices today will determine the quality and quantity of life on earth.	A3: Explore and explain any given technology that may have a different value for different groups of people and at different points in time (e.g. new varieties of farm plants and animals that have been engineered by manipulating their genetic instructions to reproduce new characteristics).						X
11	Science Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A1: Formulate testable hypothesis. Develop and explain appropriate procedures, controls, and variables (dependant and independent) in scientific experimentation.		X	X			X
11	Science Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A2: Evaluate assumptions that have been used in reaching results.						X
11	Science Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating	A3: Design and carry out scientific inquiry (investigation), communicate, and critique results through peer review.			X		X	X

		conclusions from our data							
11	Science Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data	A4: Explain why the methods of an investigation are based on the questions being asked.			X			X
11	Science Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A5: Summarize data and construct a reasonable argument based on those data and other know information.		X	X			
11	Scientific Ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A1: Analyze a set of data to derive a hypothesis and apply that hypothesis to a similar phenomenon (e.g. biome data).			X			X
11	Scientific Ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A2: Apply scientific inquiry to evaluate the results of scientific investigations, observations, theoretical models and the explanations proposed by other scientists.			X			X
11	Scientific Ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A3: Demonstrate that scientific explanations adhere to established criteria, for example a proposed explanation must be logically consistent, it must abide by the rules of evidence, and it must be open to questions and modifications.			X			X
11	Scientific Ways of Knowing	C: Explain how societal issues and considerations affect the progress of science and technology.	C9: Explain how natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by human bring benefits to society as well as risks.	X			X		X
12	Life Sciences	B: Explain how humans are connected to and impact natural systems.	B7: Relate diversity and adaptation to structure and functions of living organisms at various levels of organization.				X		X
12	Life Sciences	D: Relate how biotic and abiotic global changes have occurred in the past and will continue to	D8: Based on the structure and stability of ecosystems and their nonliving components, predict the biotic and			X			X

		do so in the future	abiotic changes in such systems when they are disturbed (e.g. introduction of non-native species, climatic change, etc.).						
12	Physical Sciences	E. Summarize the historical development of scientific theories and ideas within the study of physical sciences.	E14: Use historical examples to explain how new ideas are linked by the context in which they are conceived; are often initially rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly through contributions from many investigators (e.g. nuclear energy, quantum theory, and theory of relativity.)				X		X
12	Science and Technolo gy	A: Predict how human choices today will determine the quality and quantity of life on earth.	A3: Research how scientific inquiry is driven by the desire to understand the natural world and how technological design is driven by the need to meet human needs and solve human problems.			X	X		X
12	Science and Technolo gy	A: Predict how human choices today will determine the quality and quantity of life on earth.	A4: Explain why basic concepts and principals of science and technology should be part of active debate about the economics, politics, and ethics of various science-related and technology related challenges.	X			X		
12	Scientific Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A1: Formulate testable hypotheses. Develop and explain the appropriate procedures, controls, and variables (dependant and independent) in scientific experimentation.			X			X
12	Scientific Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A2: Derive simple mathematical relationships that have predictive power from experimental data (e.g. derive and equation from a graph and vise versa, determine whether a linear or exponential relationship exists among data in a table.)	X	X	X			X
12	Scientific Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data	A3: Research and apply appropriate safety precautions when designing and/or conducting scientific investigations (e.g. OSHA, MSDS, eyewash, goggles, and ventilation).						X

		and formulating conclusions from our data.							
12	Scientific Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A4: Create and clarify the method, procedures, controls and variables in complex scientific investigations.						X
12	Scientific Inquiry	A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from our data.	A5: Use appropriate summary statistic to analyze and describe data.	X	X	X			X
12	Scientific ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A2: Evaluate scientific investigations by reviewing current scientific knowledge and experimental procedures used, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.			X			X
	Scientific ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A3: Select a scientific mode, concept, or theory and explain how it has been revised over time based on new knowledge, perceptions, and technology.				X		X
	Scientific ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A4: Analyze a set of data to derive a principle and then apply that principle to a similar phenomenon (e.g. predator prey relationships and properties of semiconductors).			X			X
	Scientific ways of Knowing	A: Explain how scientific evidence is used to develop and revise predictions, ideas, or theories.	A8: Recognize that individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them.	X			X		

	Scientific ways of Knowing	C: Explain how societal issues and considerations affect the progress of science and technology.	C9: Recognize the appropriateness and value of basic questions "what can happen?" "What are the odds," and "How do scientists and engineers know what will happen?"			X			X	

TOPOGRAPHIC MAP ORIENTAION ACTIVITY

*Name:*______________________________________ *Date:*_______________________________

Using the 7.5-minute topographic map that includes your school, complete the exercise below. You may use the grease pencil provided to mark your answers on the laminated map.

1. ***Map Scales****:*

- Find the scale on the map. What scale is the map? ____________________________________
- How many miles is it from your school to the nearest town? Use an index card and measure from your school to a specific intersection in the nearest town)__________________________________

1. *Contours:* Locate the nearest stream to your school

- What is the elevation of the stream nearest to your school where the first tributary downstream enters?____
- Find the closest point of either the Little Miami River or East Fork of the Little Miami River to your school. What is the elevation?____

2. Orientation:

- Find the nearest city to your school on the map.______________________________________
- Draw the closest route by car from the school to the nearest city. How many miles is it?_________

3. ***Rivers:***

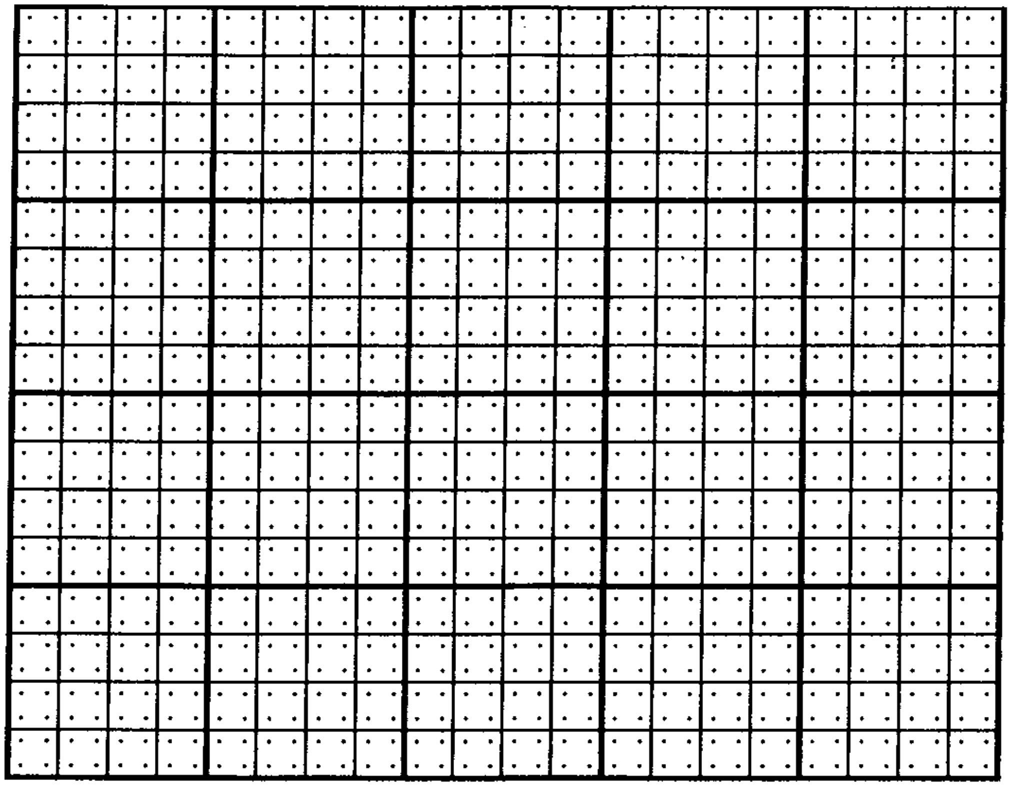
- Where does closest creek to your school enter either the Little Miami River or the East Fork of the Little Miami River? Give nearest intersection or landmark.______________________________________
- Where does the closest creek to your school go under a bridge?_____________________________

4. ***Symbols****:*

- What is the name of the closest school to your school?___________________________________
- Find a park on your map and give the closest intersection._________________________________
- Find a sewage disposal (wastewater treatment plant) to your school._________________________
- Locate some railroad tracks near your school.____
- Name the 2 four land highways that appear on the map.___________________________________
- Find the closest pond to your school.____

Source: Greenacres Foundation Make A Splash Training Manual, 1999.

DOT GRID



Map scales and equivalents

Fractional Scale	Acres Per Square Inch	Acres Per Dot
1: 24,000 (1 inch = 2,000 ft)	91.8	1.43
1: 100,000 (1 inch = 8,333 ft)	1594.0	24.9

1. Clearly draw line around area to be estimated.
2. Place dot grid randomly over area to be estimated.
3. Count all dots fully within the area plus every other dot that falls on the line around the area.
4. Record the total number of dots.
5. Repeat three times, randomly placing grid each time.
6. Take average of dot counts.
7. Multiply by appropriate acres/dot factor.

NOTE: Areas larger than dot grid may be estimated by breaking them down into smaller areas, then totaling the number of dots in each area.

Source: TVA Student Water Quality Network Teacher Training Manual, March 1992.

CALCULATING RUNOFF WORKSHEET

Student Name____________________________ Date______________________________

To calculate the amount of runoff that drains to a proposed rain garden site at the school for a specific amount of rainfall, the drainage area needs to be measured first and then the volume calculated using a specific or actual rainfall amount.

1) **Drainage Area**. (ft. x ft = sq. ft., add all types for total)

a. Pervious Surfaces (Lawn, landscape beds, and woodland — ___________ft. X _______ft = ________sq. ft.

b. Impervious Surfaces (Paved surfaces) — ___________ft. X _______ft = ________sq. ft.

c. Roof Area — ___________ft. X _______ft = ________sq. ft.

TOTAL — ________sq. ft.

2) **Rainfall** (in. /12in=ft) — ______in. / $\frac{1\text{ ft}}{12\text{ in}}$. = ________ft.

3) **Runoff Volume** (sq.ft. x ft. = cu.ft.) — ____________sq. ft. x ____ft = _______cu. ft.
(Note: sq. ft is the area and ft is the rainfall.)

4) **Gallons** (1 cu.ft. = 7.48 gallons) — ____________cu.ft. X 7.48 gal = _______gal.

***FACTOID**: An average 5 minute shower uses 25 gallons. An average 400 sq.ft. (0.5 ft. deep) rain garden captures 1500 gallons of water or 60 showers!*

SIZING A RAIN GARDEN WORKSHEET - MIDDLE SCHOOL

Name:________________________________Date:______________________

To determine the size of the rain garden, complete this worksheet.

1) Drainage Area: Measure your drainage area.
a. Roof area: ____________feet X ____________feet = _______square feet
b. Lawn area: ____________feet X ____________feet = _______square feet
c. Paved surfaces:____________feet X ____________feet = _______square feet
Total drainage area: ____________square feet

2) Soil Type: Determine your soil type using Soil Texture by Feel Key.
Please circle: sand silt/loam clay

Rain Garden Depth: Use **ONE** of the two methods below Slope **OR** Soil Factor.

2a) <u>Slope:</u> **<u>Depth:</u>**
a. Less than a 4% slope = 3 – 5 inch deep rain garden
b. 5 – 7% slope = 6 – 7 inch deep rain garden
c. 8 – 12% slope = 8 inch deep rain garden

OR

2b) Soil Factor: Use the appropriate table below to find your soil factor. The soil factor**s** derived from soil type and rain garden depth.

Table #1: Rain gardens up to 30 feet from a 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

Table #2: Rain gardens more than 30 feet from the 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

3) Rain Garden Depth: ____________inches deep

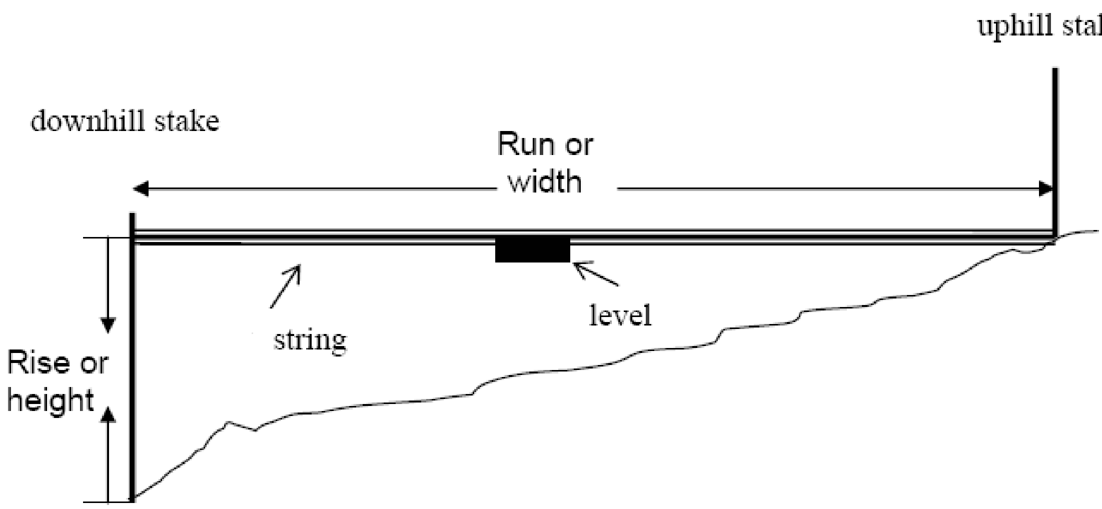
3b) Rain Garden Size: Multiply total drainage area (#1) by the Slope Percentage depth (#2a) or Multiply total drainage area (#1) by soil factor (#2b).
______(sq ft.) total drainage area X _______soil factor = ________**(sq ft.) rain garden**

**Adapted from Earth Partnership for Schools, University of Wisconsin*

SLOPE HANDOUT

Directions for measuring the slope

1. Hold the stake with the string attached at the uphill end of the measuring site. Push the string down to the bottom of the uphill stake.
2. Place the second stack at the downhill end.
3. Run the string to the downhill stake. You may need to move the stake to meet the string. The distance between the stakes is 10 feet or 120 inches. Write this number as the run on the field sheet.
4. Loop the string around the downhill stake.
5. Attach the line level to the string. It should hang down. Slide the string up or down on the downhill stake until the line level indicates the string is horizontal and level
6. Measure the height in inches on the downhill stake between the string and ground. Write this number as the rise on the field sheet.
7. If desired, repeat at a different site and trade roles.
8. Back in the classroom, calculate slope and determine depth of rain garden.



The percent slope is calculated by measuring the change in height (elevation) over a measured distance. The following formula determines slope:

Rise ÷ Run x 100 = Slope %
OR
(Change in elevation ÷ measured distance x 100 = slope %)

For example: 23‘ ÷ 100‘ x 100 = 23%

**Adapted from Earth Partnership for Schools, University of Wisconsin*

RUNOFF COEFFICIENTS

Land use - Description	Color Code for Map	Storm Runoff coefficient
Open water	Blue	0.00
Low density residential	Pink	0.40
Urban	Red	0.70
Bare rocks/sand/clay	Brown	0.80
Forest	Dark Green	0.15
Grasslands/herbaceous/shrub lands	Yellow Green	0.25
Crops/farmlands	Yellow	0.40
Urban/recreational grasses	White	0.20
Wetlands	Olive Green	0.05

Source: Indiana Geological Survey

SIZING A RAIN GARDEN WORKSHEET – HIGH SCHOOL

Name:___________________________________ Date:_________________________

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)

C: Runoff Coefficients Representing a Ratio of Runoff to Rainfall

Land use - Description	Storm Runoff coefficient
Open water	0.00
Residential	0.40
Urban	0.70
Rock/sand/clay	0.80
Forests	0.15
Grasslands/shrubs	0.25
Crops	0.40
Recreational grasses	0.20
Wetlands	0.05

CxA: Drainage Area contributing runoff times runoff coefficients:.

a. Open Water:	______acres	X	1.43	X	0.00	=	______square feet
b. LD Residential:	______acres	X	1.43	X	0.40	=	______square feet
c. Urban:	______acres	X	1.43	X	0.70	=	______square feet
d. Rocks/sand/clay:	______acres	X	1.43	X	0.80	=	______square feet
e. Forest:	______acres	X	1.43	X	0.15	=	______square feet
f. Grasslands/shrubs:	______acres	X	1.43	X	0.25	=	______square feet
g. Crops:	______acres	X	1.43	X	0.45	=	______square feet
h. Recreational grasses:	_____acres	X	1.43	X	0.20	=	______square feet
Total drainage area:							______**square feet**

I: Average Rainfall:

Largest Storm Event 1:	______average inches			/day		
Smallest Storm Event 2:	______average inches			/day		
Mean Storm Event 3:	______average inches			/day		
Average Rainfall:	______/3	=	______/12		=	____________**feet/day**

R: Rain Garden Size (volume to hold average day of rainfall)

______Total drainage area X ____________Average rainfall = ____________cubic feet

HOW TO CONDUCT A PERK TEST

STEPS:

1. Dig 8“diameter and 8” deep hole with a trowel.
2. Fill hole with water and let saturate for an hour.
3. Refill Hole and use pencil jabbed in side of hole to mark top of water level.
4. Use ruler to measure distance from the pencil to top of water. Visit the hole every hour or so until it drains completely. Measure it each time but only use one measurement and time for the calculation, preferably the last measurement.
5. Calculate how much water will infiltrates in inches per hour. . The goal is a Rain Garden that will drain in 24 hours.

   _______Inches/________time (in hours) = _______Inches/hr.

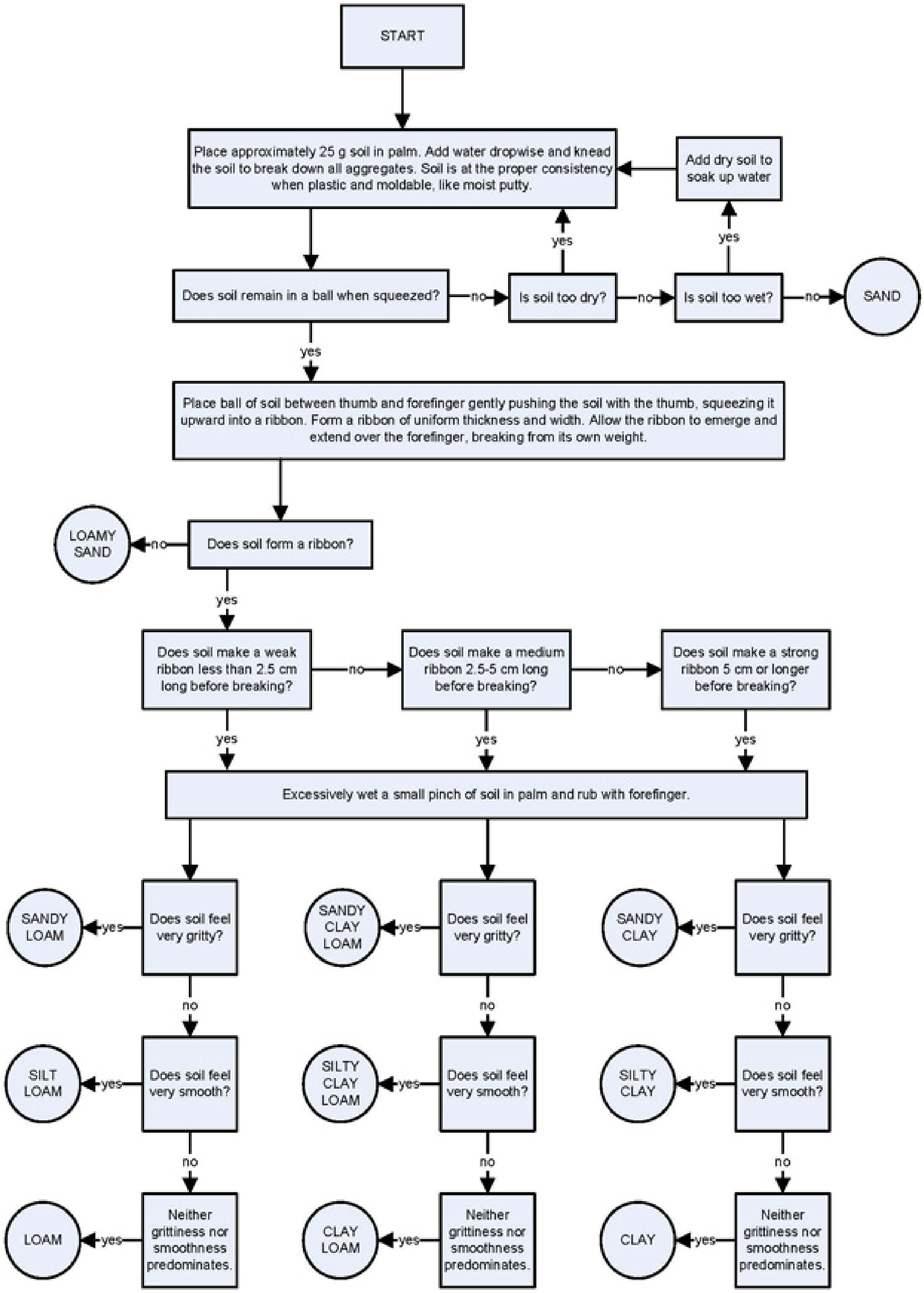
   Example:
   0.5 inches/ 90 minutes (convert 90 minutes to1.5 hr) = 0.33 inches per hour

6. Use perk test results to select a depth for the rain garden that will drain in 24 hours.

   If your garden drains 0.33 inches per hour, in 24 hours it will drain 7.92 inches. So your rain garden should not exceed 8 inches deep.

Photo Source: Rusty Schmidt, Washington Soil and Water Conservation District, Minnesota, Wisconsin.

KEY TO SOIL TEXTURE BY FEEL



Modified from S.J. Thien. 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomic Education. 8:54-55.*

PLANT WORKSHEET

Name________________________________ Date____________________

Plant Name:____

Botanic Name:

Sun Shade Preference:____

Moisture Requirements:____

Will plant survive inundation with water?_____________________________________

Bloom Color:____

Bloom Time:____

Fall Color:____

Other Ornamental Features
(seed, fruit, bark, etc.):____
____

Relationship to theme: (wildlife habitat,
butterfly habitat, edible plant, scent plant, etc)_______________________________
____
____
____

Plant Photo or Drawing:

PLANT EVALUATION TABLE

Name____ Date_____________

Plant Name	Botanic Name	Height	Spread	Sun/ Shade Preference	Moisture Requirements	Will survive standing water?	Bloom Color	Bloom Time	Fall Color	Other Ornamental feature	Use in Theme (optional)

RAIN GARDEN SPECIES SELECTION CRITERIA WORKSHEET

Name_____________________________________Date:________________

Location: _________________________________Size: ___________ (sq ft)

<u>Environmental Conditions:</u>

Circle the site characteristics that describe your site.

Soil Type:	Sand	Silt/Loam	Clay
Percent Slope:	less than 4%	5% - 7%	8% - 12%
Light:	Full sun	Partial shade	Shade

<u>Rain Garden Specifications</u>

Complete section below based on site conditions and your rain garden design goals.

Garden Size (sq.ft.)__________Number of plants needed (1 plant/square foot):________

Ecosystem type (Habitat): Prairie (sun) Savanna (part sun) Woodland (shade)

Desired plant type(s): (circle all that apply.)

Grasses Sedges Wildflowers Ferns

Shrubs Trees Other___________________________

Height Requirements: Minimum height:_______________Maximum height:________

Desired Bloom Times:

____Spring (April – May) ____Early Summer (June),

____Summer (July) ____Late Summer (August),

____Fall (September – October)

<u>Additional Criteria</u>

Identify criteria that fit your project goals such as flower color, texture, fragrance, wildlife value, etc.

____

____

____

____

____

Adapted from Earth Partnership for Schools, University of Wisconsin.

MEASURING UP
EXAMPLE BUTCHER PAPER PLANT SUCCESS RECORD

Plant Name	**Week 1 Rainfall Amount:** 0.0 inches	**Week 3 Rainfall Amount:** 0.0 inches	**Week 3.5 Rainfall Amount:** 0.5 inches	**Week 5 Rainfall Amount:** 0.0 inches
Black-eyed Susan	Healthy and growing	Healthy and Growing	No Change	Flowering
Indian Grass	No change	Healthy and Growing	No Change	No change
Sweet Shrub	No Change	No Change	No change	Rabbit damage

RESOURCES

RESOURCES SITED IN LESSON GUIDE:

The Blue Thumb Guide to Raingardens by Rusty Schmidt, Dan Shaw, and David Dods, Waterdrop Innovations, LLC, 2007.

City of Maplewood. Rain Garden Design and Construction Worksheet. Maplewood: City of Maplewood, 2007.

Creek Connections Topographic Map Module:
http://creekconnections.allegheny.edu/Modules/TopographicMaps.html

Degrees, Minutes, Seconds and Decimal Degrees Latitude/Longitude Conversions:
http://www.fcc.gov/mb/audio/bickel/DDDMMSS-decimal.html

Earth Partnership For Schools – University of Wisconsin:
http://uwarboretum.org/eps/research_act_classroom/rain_garden_curriculum.php

A flow diagram for teaching texture by feel analysis, S.J. Thien. Journal of Agronomic Education. 8:54-55, 1979.

Free online landscape design software like http://www.showoff.com/; or *free trials of landscaping programs* such as www.ideaspectrum.com.

Give Water A Hand, http://www.uwex.edu/erc/gwah/

A How-to Manual for Homeowners. Board of Regents of the University of Wisconsin System. Rain Gardens: UWEX Publication, 2003.

Runoff Coefficients Table, Indiana Geological Survey:
http://igs.indiana.edu/survey/projects/hydrotools/html_files/element2.cfm.

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

Start-to-Finish Rain Garden Design A Workbook for Homeowners, Faribault County Soil & Water Conservation District with funding from MPCA and 319.

Terra Server, http://terraserver-usa.com/ or
http://mapserver.mytopo.com/homepage/index.cfm?CFID=3692819&CFTOKEN=19169154.

TVA Teacher Student Monitoring Network Teacher Training Manual, Tennessee Valley Authority, 1992.

Undeveloped vs Developed Infiltration Rates illustration, Stream Corridor Restoration: Principals, Processes, and Practices, Federal Interagency Stream Restoration Working Group (FISRWG). October 1998.

Watershed Woes, activity, Environmental Resources Guide: Nonpoint, Grades 9-12, Air and Waste Management Association, 1993.
http://secure.awma.org/OnlineLibrary/ProductDetails.aspx?ProductID=87

PRINTED RESOURCES *(Distributed to Teacher in Clermont OEEF Project):*

The Blue Thumb Guide to Raingardens
Locally these books can be purchase for $18.00 from the Greater Cincinnati Rain Garden Alliance by calling (513) 563-8800. The book is also for sale through www.Amazon.com; search for Rain Garden and this is the first book that comes up. You can also purchase the book from: www.TerraceHorticulturalBooks.com.. For bulk orders of 10 or more copies, visit www.Raingardens@yahoo.com or call Rusty Schmidt at 612-703-8695. This book is published by Water Drop Innovations Inc.

Plants for Storm Water Design (Volumes I and II)
Volume I and Volume II are both available. Volume I is $15.95 and Volume II is $27.95. There is a discount if you order both; Volume I and II combined is $34.95. These prices do NOT include tax or shipping/handling. They take major credit cards. To order, visit this website to obtain and order form: http://www.greatrivergreening.org/publications.asp. Then fax the order to them at: 651-665-9409.

WEB_BASED RESOURCES:

Cincinnati Zoo and Botanical Garden Regional Plant Places Rain Garden Plant Database:
http://www.plantplaces.com/raingardenindex.shtml

Kids Gardening – Rain Garden Activities: http://www.kidsgardening.com/themes/raingarden.asp

LID Sustainable School Projects – Rain Gardens: http://lowimpactdevelopment.org/school/bioret/brm.html

Maplewood, Minnesota Rain Garden Project: http://www.ci.maplewood.mn.us/index.aspx?NID=456

Maplewood: Creating Your Own Rain Garden:
http://www.ci.maplewood.mn.us/DocumentView.aspx?DID=247&DL=1

Maplewood Rain Garden Designs: http://www.ci.maplewood.mn.us/index.aspx?NID=457

Northern Rhode Island Conservation District: http://nricd.org/studentlessons.htm

Stormwater Curriculum : http://www.danewaters.com/pdf/stormWaterCurriculum.pdf

Rain Garden Network School Gardens: http://www.raingardennetwork.com/schoolgardens.htm

Rain Gardens a Service Learning Project: http://asstudents.unco.edu/students/AE-Extra/2007/5/Carlson.html

Rain Gardens of Western Michigan: http://www.raingardens.org/Rain_Gardens.php

The Rhodale Kids – Re Gen Page:
http://www.kidsregen.org/educators/educators2.php?section=eduNga&ID=11#schoolyard

Teaching With Topographic Maps - 25 Ideas for Educational Lessons:
http://rmmcweb.cr.usgs.gov/outreach/topoteach.html

SW OHIO RAIN GARDEN PLANT SOURCES

Greenfield Plant Farms, http://www.greenfieldplantfarm.com/, Phone: (513) 683-5249

J F New (mail order), http://www.jfnew.com/, Phone (574) 586-2412

Keystone Flora, LLC , http://www.keystoneflora.com/, Phone: (513) 961-2727

Marvin's Organic Gardens, http://www.marvinsorganicgardens.com/, Phone: (513) 932-3319

Mary's Plant Farm, http://www.marysplantfarm.com/, Phone: (513) 894-0022

Prairie Moon (catalog), http://www.prairiemoon.com/, Phone: (866) 417-8156

MONITORING EQUIPMENT

Equus 3660 Hand Pump Kit, Part # EQUUS3660, Best Brands, 866-553-8116 or 989-839-4877 , www.Auto-Repair-Manuals.com

Garmin eTrex H Handheld GPS Navigator, Part Number: 010-00631-00, Garmin, 800-800-1020 https://buy.garmin.com/shop/shop.do?cID=143

Garner Industries Basic Rain Gauge, Part # GAI-820-0409, Best Nest, 1-877-562-1818, www.bestnest.com

Hach Just Add Water Level 2 Water Monitoring Kit, Part # 278770, Hach Company, (800) 277-4224, www.hach.com

Hach Phosphate Cube Test Kits, Part #125220, Hach Company, (800) 277-4224, www.hach.com

Hach Nitrate-Nitrogen Cube Test Kit, Part #1403700, Hach Company, (800) 277-4224, www.hach.com

Hach Multi-test Kit Case, Part # 4661000, Hach Company, (800) 277-4224, www.hach.com

HM Digital Economy TDS Meter (TDS-4), HM Digital Water Testing Supplies, 800-383-2777, http://www.tdsmeter.com/products/tds4.html

HM 342 ppm NaCl Calibration Solution, HM Digital Water Testing Supplies, 800-383-2777, http://www.tdsmeter.com/products/tds4.html

Luster Leaf 1880 Rapitest Electronic 4-way analyzer, Luster Leaf Gardening Products Inc., Part # 035307018809, 1-800-327-4635 http://www.lusterleaf.com/Meter/pages/1880.html

Metal Meter/ Yard Stick (Can be purchased at any hardware store)

Topographic Maps, USGS Map Store, 888-275-8747, http://store.usgs.gov/b2c_usgs/b2c/start/(xcm=r3standardpitrex_prd)/.do