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 programs compare rain garden performance to the performance of other storm water Best Management Practices or BMPs such bioswales, retention basins, rip rap, and or pervious or semi-pervious materials like pervious asphalt or pavers.

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 completely 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 completely 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. Using a measuring tape and stakes, 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 at stake #1. 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. Now examine the elevations at each of the stakes at all of the intervals and create circles connecting all points of the same elevation. This is the isopleth. Your drawing will look sort of like a topographic map. Now pound in one yellow tent stake at every elevation in a line from the highest to the lowest. For example, you might have a stake at the 1 inch, 3 inch, 5 inch, and 8 inch elevations. Choose the elevations that work for your situation. 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.

Plant Success

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? Do plugs work better than quart size plants? Gallon size plants?
4) Which plants are growing the best? Why? Compare what you knew about the plants preferences from your research about the plants to the plants actual performance in your rain garden.
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? Some 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 Total Dissolved Solids or 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:

Option 1: Elementary School

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 readings 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 filtered 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 storing using their rain gauge data, measurement of their rain garden's drainage area, and measurement of their rain garden's actual size? 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 at different depths/locations and testing different 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 need 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 study topic 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 predetermined period of time 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.