



Stormwater Management Lesson Plans for Grades 3-12

Green Infrastructure as Outdoor
Environmental Laboratories:
Urban Water Quality Training in
Primary and Secondary Schools





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Environmental Laboratories:
Urban Water Quality Training in Primary
and Secondary Schools

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Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE





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Executive Summary

This booklet includes a set of lesson plans for 3-12 school teachers that enable environmental and STEM learning opportunities to be taught on school grounds. The focus of the lesson plans is on improving local water quality through schoolyard interventions. The interventions include rain gardens, rain barrels, green roofs, permeable paving, etc. Environmental topics include hydrology, soil properties and plant communities. Science lessons are practiced through repeated observation, analysis and systems modeling.

Each lesson plan lists NextGen Science Standards and Maryland Environmental Literacy Standards that relate to the given lesson. The lesson plans were developed in collaboration with school teachers from elementary, middle and high schools located in the Anacostia River watershed of Maryland and Washington, DC.

Teachers can follow the plans directly or modify them as appropriate to fit their curriculum needs and onsite opportunities. Our hope is that teachers who use these lesson plans will also find ways, along with their students, to make positive changes on their school grounds that will lead to improved water quality for their local community.

Stormwater Management

Introduction

Best Management Practices

Teaching students techniques that improve water quality in lakes and streams

Stormwater runoff is water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves. The water quality of rivers, streams, lakes and ponds are adversely impacted by contaminated stormwater runoff. Recent developments in stormwater management include a set of site level best management practices (BMPs) that capture and store stormwater runoff while filtering out sediment, pollutants and debris. These practices can be implemented by students, teachers and families on school grounds and at home.

The lesson plans in this document introduce students to the important concepts in science, technology, and environment systems related to stormwater runoff and water quality. They are based on the following list of BMPs.



Rain Garden or Bioretention Cell

Bioretention: the process in which contaminants and sedimentation are removed from stormwater runoff by holding and infiltrating water into the ground.

Rain Garden: a planted depression that infiltrates and cleans stormwater runoff. Rain gardens have native plants that can tolerate wet and dry conditions common to the specially designed porous soils.



Rain Barrel

A system that collects and stores rainwater from your roof in barrels. It is to ensure that polluted water does not become runoff and flow into storm drains or streams.



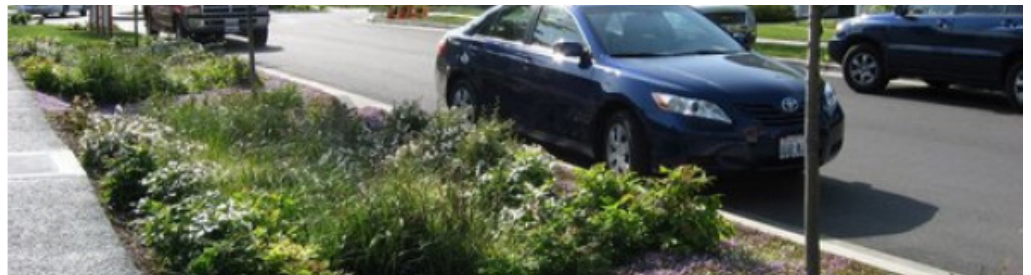
Permeable Paving

A hardscape surface that allows water to infiltrate through them into the ground or an underdrain. These include porous asphalt, permeable pavers, pervious concrete, and aggregate.



Green Roof

A roof designed to grow vegetation using a layered system that includes a growing medium, a drainage layer and waterproofing. Green roofs have many benefits including stormwater storage and heating and cooling efficiencies.



Bioswale

A graded landscape feature appearing as a linear, shallow channel. They are usually vegetated and help move and filter stormwater at a controlled rate.



Science Standards

Maryland Environmental Literacy Standards (See Appendix A)

The Maryland State Department of Education (MDOE) developed standards for environmental literacy. The purpose is to: "...enable students to make decisions and take actions that create and maintain an optimal relationship between themselves and the environment, and to preserve and protect the unique natural resources of Maryland, particularly those of the Chesapeake Bay and its watershed."

To assist in achieving these goals, the lesson plans in this booklet identify specific MDOE standards associated with each lesson plan. The complete set of Maryland Environmental Literacy Standards is provided in the appendix for convenience. The standards are coded in shorthand as shown in the following example:

CODE	STANDARD
MD 1.A.1	Standard 1, topic A, Indicator 1: Identify an environmental issue.

Although these lesson plans have explicit sets of instructions, they should be seen more as flexible templates. Teachers and administrators may consider modifying the lesson plans as needed to fit specific curriculum needs or changes in MDOE standards over time.

Next Generation Science Standards (See Appendix B)

Addressing the needs for scientific and technological literacy to prepare students for a modern workforce, a partnership of leading national organizations developed "A Framework for K-12 Science Education."

The comprehensive set of standards, known as Next Generation Science Standards (NGSS) is too large to include in this document but can be accessed at <http://www.nextgenscience.org>. The specific standards applicable to these lesson plans are provided in the appendix for convenience.

The lesson plans in this booklet offer learning opportunities that map to the standards developed for NGSS. The standards are coded in shorthand as how in the following example:

CODE	DESCRIPTION
3-ESS3-1	Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.

Lesson Plans

- Site Inventory (Mapping your school grounds)
- Site Analysis (Assessing your school grounds)
- Green Roofs
- Rain Barrels
- Rain Gardens
- Rain Garden Plants
- Soils
- Permeable Pavement
- Hydrology

Stormwater Management

Site Inventory

Overview

Students will gain an understanding of how to map stormwater features on a site.

Grade Level

6 - 12

Science Standards

MD 1.A.1, MD 1.B.1, MD 2.A.1, MD 5.A.1, MD 5.A.2, MD 7.A.1, 3-ESS3-1, 3-5-ETS1-2, 4-ESS2-1, 4-ESS2-2, 4-ESS3-2, MS-ETS1-3, HS-ETS1-3

Time

90 mins

Teacher Difficulty



Group Size

3 - 4 Students

Materials

- Handouts (one per student): Vocabulary, Site Inventory Symbols, Site Inventory Questions, Site Inventory Samples
- Journal or paper for recording observations and writing utensils

PROCEDURE

Objectives

- Learn what landscape architecture is and why it is important to stormwater design
- Learn what a site inventory is and how to conduct one
- Perform a site inventory to determine the best location for BMPs

Warm Up Activity

Evaluate prior knowledge and introduce new terms through class discussion

1. What is Landscape Architecture?

Answers will vary. Landscape architecture is a multidisciplinary field that combines aspects of biology, civil engineering, horticulture, hydrology, architecture, art, ecology, and much more. It is the design of outdoor spaces such as parks, gardens, streetscapes, residences, etc. There are many different methods and goals. One of the first things a landscape architect has to do in design is complete a site inventory.

2. What is Site Inventory?

Answers will vary. Site inventory is one of the first stages of the design process that involves identifying, observing and recording different features on the site such as stormwater flow, vegetation, sun and shade patterns, wildlife habitat, and elevation changes.

PROCEDURE CONTINUED

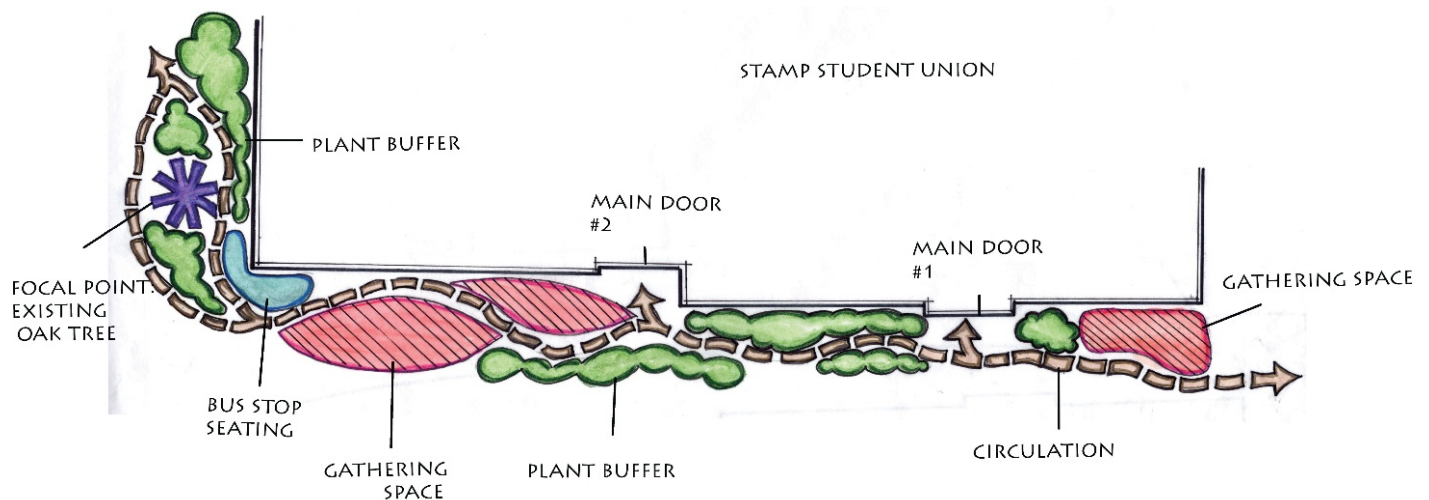
Introductory Activity

Introduce vocabulary and discuss the different aspects of a site that Landscape Architects record as part of their site inventory

Hand out the Site Inventory Vocabulary Sheet and review it with the students. Discuss the different features they will be recording. These include: plants, moving water or ponding, slopes, high points and low points, erosion, downspouts, impervious surfaces, buildings, sun and shade patterns, and wildlife. Students will be using their site inventories to determine the best locations on the site for different stormwater management facilities.

Hand out the Site Inventory Symbols and Samples Sheet. These are the symbols the students should use to mark their observations on their maps. Usually Landscape Architects record much more than what is listed on the sheet, but the goal of this lesson is to focus on stormwater.

SITE INVENTORY SAMPLE



Developmental Activity

Show students different examples of site inventory maps

Go over a few examples and talk about the different symbols you see. Students should use the symbols on their handouts, but they can add symbols for other observations they make if they choose to.

SITE INVENTORY SYMBOL EXAMPLES



Ponding



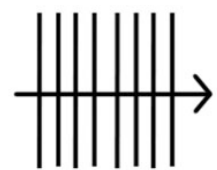
Shady Area



Sunny Area



Water flow



Steep Slope

PROCEDURE CONTINUED

Guided Practice Activity

Walk around school grounds with students to record observations

Give each student a map of the school grounds to record their findings. If available, give each student a clipboard to use while drawing. Students can work in small groups or individually, but each should produce their own inventory map. If the property is exceptionally large, students can split into groups to record separate areas. Have students focus on stormwater elements first, including ponding, impervious surfaces, and stormwater flow lines.

Independent Task Activity

Color maps and discuss observations

Students should use this time to make their maps readable and colorful. Make sure they use the symbols given on the symbols handout so the maps are consistent between students. Students should talk in small groups and share their maps and observations.

Assessment Activity

Discuss complete inventory maps with the whole class

Students can pin their maps up on the wall and walk around to review each other's maps. Discuss the different observations that were made. Have students explain what they noticed and how they labeled it. Have students answer the **Observations Questions Sheet**. Collect inventory maps for future use.

Closing

Discuss why Landscape Architects take site inventories and introduce site analysis

This can be a quick discussion and review of the lesson. Landscape Architects do site inventories to become familiar with all of the features on the site in order to make better design decisions.

Extension Activity

Expand knowledge of site inventory with activities out of the classroom

- Students can neaten maps and add in any missing symbols at home
- Students can make a site inventory map of their own yards at home

HELPFUL HINTS

If necessary, do a preliminary walk around the school property to get familiar with the site. Take note of the things things students should record.

Sketch or make copies of a map of the school grounds from Google.

**Stormwater
Management**

Site Inventory KWL Sheet

What I Know**What I Want to Know****What I Learned**

Circulation

The areas and directions in which vehicles, bicycles, and pedestrians travel. A map of the most trafficked areas on a site.

Detention pond

A pond built with the purpose of holding stormwater temporarily until it can be drained or infiltrated elsewhere.

Downspout

A pipe that carries rainwater from a roof gutter. Downspouts are typically vertical and lead water off of a roof to the ground.

Erosion

The slow removal and wearing away of soil on the earth's surface by water, ice, wind, etc.

Flow Path

A path that stormwater takes when travelling across the landscape.

Focal Point

A point or feature on the site that draws one's attention.

High Point

The highest point of elevation on the site. Every point on the site should be downhill from this point. A relative high point is the highest point in a certain part of the site.

Impervious surface

An impenetrable surface that does not allow water to filter through it. It is typically a man-made surface such as asphalt, concrete, etc.

Landscape Architecture

A multi-disciplinary profession that combines architecture, engineering, biology, horticulture, ecology, and design. Professionals design outdoor spaces such as gardens, parks, streetscapes, campuses, and residences.

Low Point

The lowest point of elevation on the site. Every point on the site should be uphill from this point. A relative low point is the lowest point in a certain part of the site.

Pervious surface

A surface made out of material that is porous enough to allow water to filter through it. These surface types can vary, but they include soils and groundcovers, permeable paving, etc.

Ponding

The build-up of water in a certain location due to poor drainage.

Retention pond

A pond built with the purpose of holding water permanently. Some water will be lost to evaporation, but the pond will pretty much always have standing water from a rain event.

Site Inventory

One of the first stages of the design process that involves identifying, observing and recording different features on the site such as stormwater flow, vegetation, sun and shade patterns, wildlife, habitat, and elevation changes.

Storm Drain

A metal grate in the landscape used to collect and divert stormwater into a sewer system.

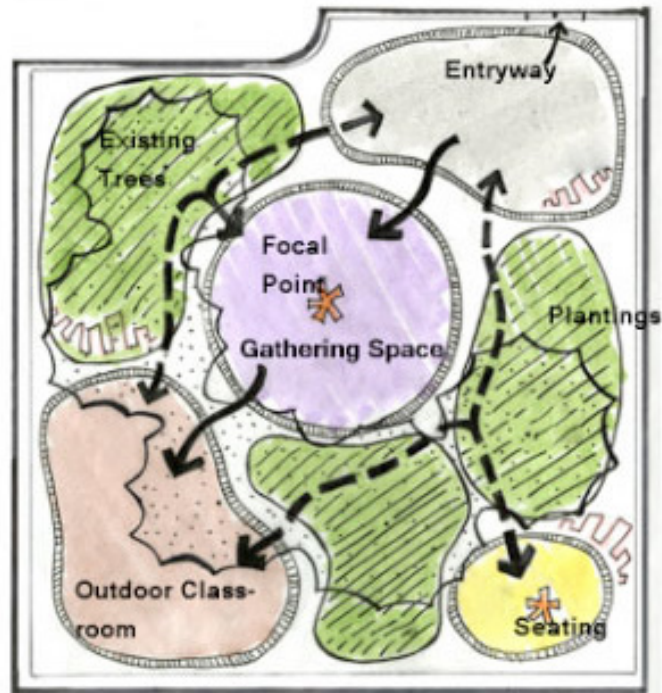
Stormwater Management

Site Inventory Samples

The following are varying examples of site inventory maps

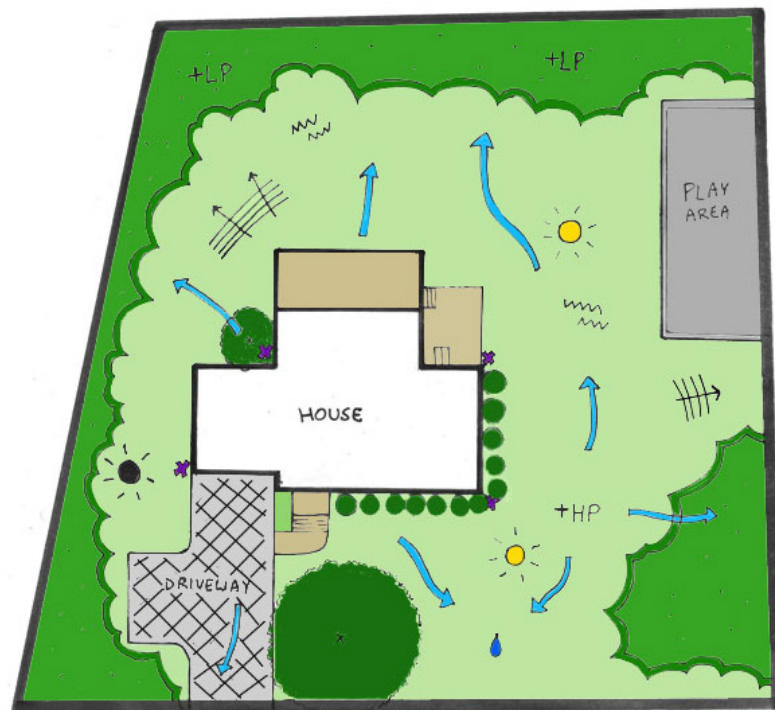
Example 1

Shows circulation paths, vegetation, existing trees, focal points, and gathering spaces. This is a basic site inventory because it labels different features, existing patterns and uses currently on the site. Colors can be effective in differentiating spaces.



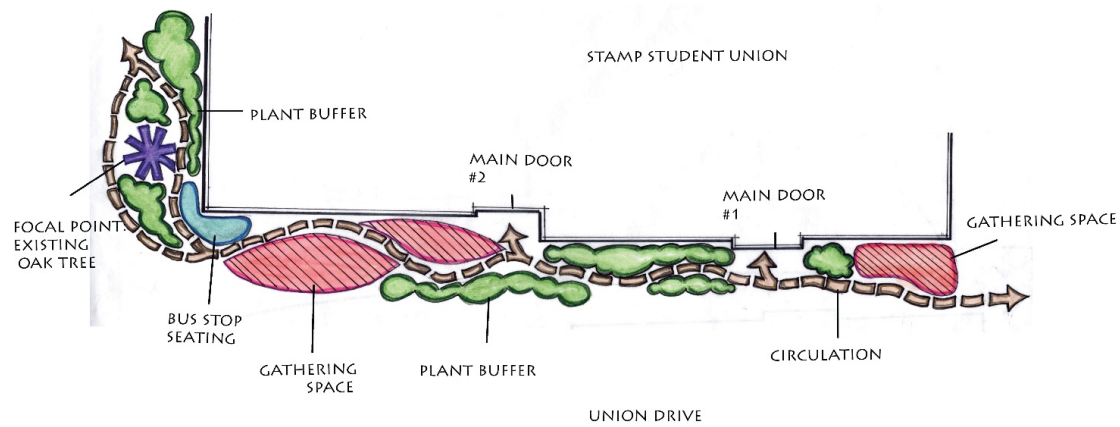
Example 2

This site inventory focuses on the path of water flow, sun/shade patterns, high and low points, downspouts, and vegetation. This focuses on the location and movement of stormwater as well as plant information.

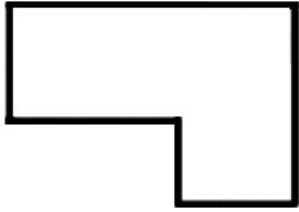


Example 3

This site inventory focuses on circulation, vegetation, existing gathering spaces, and focal points. This inventory includes context such as entrances to the site and neighboring roads.



Site Inventory Symbols



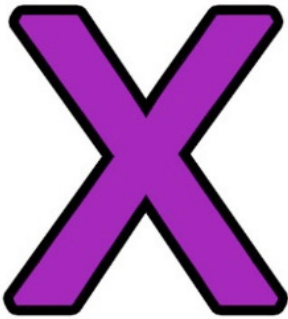
Building Outline



Low Point



High Point



Downspout Opening



Shady Area



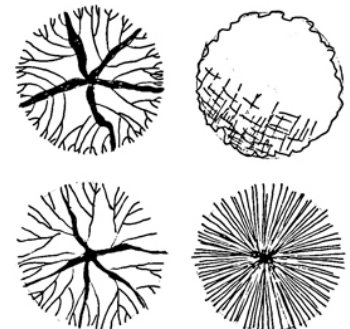
Sunny Area



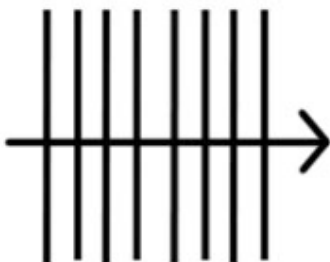
Ponding



Erosion



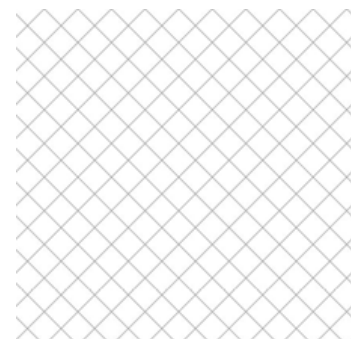
Trees and Shrubs



Steep Slope



Water Flow



Impervious Pavement

Site Inventory Questions

Fill out answers in the space below the questions

Question 1

What were some of the observations you made while out on the school grounds?

Question 2

Were there any areas of the property that you think are underutilized?

Question 3

Did you observe any drainage issues in the form of puddles, erosion, or standing water anywhere on the site?

Question 4

If you were a landscape architect and you were told to re-design the school property, how would you design it? (Write or draw your answer).

Stormwater Management

Site Analysis

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of site analysis

6 - 12

MD 1.A.1, MD 1.B.1, MD 2.A.1, MD 5.A.1, MD 5.A.2, MD 7.A.1, 3-ESS3-1, 3-5-ETS1-2, 4-ESS2-1, 4-ESS2-2, 4-ESS3-2, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, HS-ETS1-3

90 mins



1 - 3 Students

- Handouts (one per students): Vocabulary, Site Analysis Question Sheet
- Markers or colored pencils
- Clipboard or surface to write on
- Map of the school grounds (new copies of site inventory map)

PROCEDURE

Objectives

- Learn what site analysis is and why it is important for design
- Perform a site analysis
- Learn about stormwater BMPs (see pages viii - ix) and how to determine where they should be implemented

Warm Up Activity

Evaluate prior knowledge through class discussion

What is site analysis and why is it important?

Answers will vary. Site analysis is one of the first stages of the landscape architecture design process that involves analyzing observations made on a site relating to stormwater, vegetation, wind patterns, sun and shade patterns, wildlife habitat, and elevation change. Analysis should be done in order to better one's understanding of design possibilities. Site analysis is important to do before designing a site because it helps one understand what issues or opportunities there are on the site. By first analyzing the site features, you can then determine the best design for the site.

Introductory Activity

Introduce vocabulary and review stormwater BMP examples

Hand out **Site Analysis Vocabulary Sheet** and review site analysis terms. Review previously learned BMPs as they will be needed for this exercise.

PROCEDURE CONTINUED

Developmental Activity

Introduce the difference between site inventory and site analysis

Make sure the students understand site analysis enough to make their own examples of it. Write an example or two on the board so they understand the difference between site inventory and site analysis. For example:

Site Inventory: There is a lot of water draining from the corner of the roof.

Site Analysis: Runoff from the roof may cause erosion and carry sediment to the stream. A rain barrel could capture the roof water and release it slowly through a valve.

Guided Practice Activity

Have students mark on their maps the places where they think the different stormwater BMPs could be implemented

Take students outside to the previously visited area where the site inventory was conducted. Bring site inventory maps. Students should take note of each of their points from their site inventory. At each point they should decide:

- a. If a BMP could go in that area
- b. Why or why not
- c. If yes, which BMP would be the best for that location

Independent Task Activity

Have students choose one BMP that they found a place for on the site

Have students draw a quick sketch of the BMP they chose from their site analysis map. The sketch should show what the BMP would look like in their chosen place and how the stormwater would flow through the system.

Assessment Activity

Share and discuss the students' site analysis maps

Students can pin their maps up on the wall and walk around to see each other's findings. Discuss the different analyses the students made. Where were the common places that students put BMPs. What were similarities and differences between the maps? Were any BMPs not chosen by any students? If so, why not?

Have students discuss the potential for BMPs to be installed on the school property. Students should fill out the Observation Questions Sheet at this time.

PROCEDURE CONTINUED

Closing

Connect the lesson back to Landscape Architecture

Remind students that Landscape Architects do site analysis every day as part of the design process. Discuss Landscape Architecture and encourage the students to look into stormwater management further.

Extension Activity

Expand knowledge of site analysis with activities out of the classroom

- Students can locate more spaces they deem fit for a stormwater BMP and draw a more detailed map of how they would look and where they would go on the site.
- Students can make a site analysis map of their own yards at home
- Students can create artwork or written works based on their stormwater management ideas.

HELPFUL HINTS

If necessary, do a preliminary walk around the school property to get familiar with the site. Take note of the things things students should record.

Use the same map from the site inventory.

Be sure to hold onto students' site inventory maps or collect them at the end of the prior lesson to have available for later use.



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DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

Stormwater Management

Site Analysis Vocabulary

BMP

Best management practice.

Canopy Trees

Trees that have a wide spread to provide shade and catch rain water.

Green Roof

A roof with vegetation and a system that has a growing medium and a waterproofing layer. Green roofs have many benefits such as storing rain water and reducing the urban heat island effect.

LID

Low impact development. Design that works to treat stormwater as close to the source as possible to prevent erosion and polluted water sources.

Permeable Pavement

A hardscape surface that allows water to infiltrate through it into the ground or an underdrain. These include porous asphalt, permeable pavers, pervious concrete, and aggregate.

Rain Barrel

A system that collects and stores rainwater from your roof in barrels. It is to ensure the polluted water does not become runoff and flow into storm drains or streams.

Rain Garden

A planted depression that infiltrates and cleans stormwater runoff.

Site Analysis

One of the first stages of the design process that involves analyzing observations made in a site relating to stormwater, vegetation, wind patterns, sun and shade patterns, wildlife habitat, and elevation change. Analysis should be done in order to better one's understanding of design possibilities.

Stormwater Management

The treatment of stormwater runoff in order to minimize flooding, pollution, and other hazards while improving water quality for aquatic and terrestrial habitat.

Stormwater Runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves.

Swale

A graded landscape feature appearing as a linear, shallow channel. They are usually vegetated and help move and filter stormwater at a controlled rate.

Site Analysis Questions

Fill out answers in the space below the questions

Question 1

Explain the difference between site inventory and site analysis (your two maps may help).

Question 2

What stormwater BMPs did you find most appropriate for the site?

Question 3

Pick one BMP you think could be put on the site and elaborate your reasoning.

Question 4

Were there any BMPs that you did not find a spot for on the site? How come? What type of conditions would be right for that BMP?

Stormwater Management

Green Roofs

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of green roof functions and benefits

3 - 5

MD 5.A.2, MD 7.F.1, 5-ESS3-1, HS-ESS3-4

60 mins



3 - 4 Students

- Handouts (one per student): KWL, Vocabulary, Questions, Crossword
- Construction paper (multiple colors)
- Grid paper or blank paper
- Colored writing utensils

PROCEDURE

Objectives

- Learn what a green roof is and why it's important
- Understand the benefits of a green roof
- Design a green roof

Warm Up Activity (5 mins)

Evaluate prior knowledge of green roofs by completing a KWL Chart

Hand out the KWL Chart and allow table groups (3-4 students) about two minutes to come up with as many things they know or wonder about green roofs. Each table group will share with the class at least two things they discussed. Make sure students complete 'what I learned' during the review.

Suggested questions to ignite brainstorm activity:

1. What is a green roof?
2. What makes a green roof?
3. What is the purpose of a green roof?
4. Are there different types of green roofs?

Introductory Activity (7 mins)

Introduce Green Roof Vocabulary Sheet and discuss green roof elements

Hand out the Green Roof Vocabulary Sheet and Crossword. Review all vocabulary words with the students and complete crossword.

PROCEDURE CONTINUED

Developmental Activity (8 mins)

Show students examples of green roofs from around the world

Show green roof examples on screen to the whole class. Point out the range of sizes and locations of green roofs. Have students compare and contrast the different examples.

Guided Practice Activity (10 mins)

As a group, have students answer the following questions:

1. *What are the benefits of green roofs?*
 - a. Extend the life of your roof by reducing temperature fluctuations that can damage roofing materials
 - b. Provide additional insulation for your home, which conserves energy and saves money
 - c. Reduces runoff from your home by absorbing stormwater, which can help alleviate any drainage or runoff problems that occur in your yard.
 - d. Improves air quality - plants take up carbon dioxide and release oxygen
 - e. Create peaceful retreats for people and animals
2. *What are the layers of a green roof?*

Green Roof Layers

- 1 Vegetation
- 2 Growing medium
- 3 Drainage layer
- 4 Waterproof membrane
- 5 Roof deck



Independent Task Activity (15 mins)

Students will work in groups to design their own green roof

Teachers can choose to give students either grid paper or blank paper for this activity. Students can make an aerial view of their design by drawing a view from above of vegetation, structures, paths, etc. or they can draw a perspective view of how their site would look if they were to walk around on their green roof. This will allow students to be creative and get a sense of all the different possibilities there are when designing a green roof.

PROCEDURE CONTINUED

Assessment Activity (10 mins)

Discuss and review designs

Pin up the different green roof designs and discuss what the students learned. Have students complete the Rain Gardens Question Sheet then glue or tape the paper into their interactive science journals.

Closing (5 mins)

Summarize the lesson and reiterate the benefits of green roofs.

Connect discussion back to stormwater and the different types of stormwater BMPs. Have students fill out “What I learned” part of KWL

Extension Activity

Expand knowledge of green roofs with activities out of the classroom:

- Students can research what kinds of plants and materials are the best for green roofs. They can further develop their green roof designs with more specific information.
- Students can pick one example of a green roof from anywhere in the world that was not shown in class. They can do some research on where it is, the type of green roof, the plants used, and the type of building it is on.

HELPFUL HINTS

The crossword can also be completed at home as homework if there is not enough time to complete it in the classroom.



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**Stormwater
Management**

Green Roofs KWL Sheet

What I Know

What I Want to Know

What I Learned

Stormwater Management

Green Roofs Vocabulary

Drainage Layer

A layer in a green roof structure that leaves space for rainwater collect and infiltrate before excess water leaves the roof.

Extensive

A green roof with a shallow layer of growing medium. These green roofs use smaller, more resilient plants, cost less than larger green roofs, and do not hold much weight.

Green Roof

Planted roofs that help capture and treat rain water before it becomes runoff. Green roofs can provide an attractive environment, improve air quality, provide health benefits, lower energy costs, and provide habitat.

Growing Medium

The material in which plants grow. Soil is a common growing medium but not the only one.

Impervious Surface

An impenetrable surface that does not allow water to filter through it. It is typically a man-made surface such as asphalt, concrete, etc.

Infiltration

The process by which water on the ground surface enters the soil.

Intensive

A green roof that has a thick layer of growing medium, can hold much more weight than extensive green roofs, and can have a larger variety of plants and other structures on top of it.

Low Impact Development (LID)

Design that works to treat stormwater as close to the source as possible to prevent erosion and polluted water sources.

Pervious Surface

A surface made out of material that is porous enough to allow water to filter through it. These surface types can vary, but they include soils and groundcovers, permeable paving, etc.

Soil

Soil is composed of living organisms, rock particles, water, air, and organic matter, such as dead or decomposing organisms. This is an ideal growing environment for many plants.

Stormwater Runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves.

Waterproof Membrane

A layer in a green roof structure that prevents water from leaking through the rooftop and into the building.

Stormwater Management

Green Roofs Crossword

Use the clues provided to fill out the crossword

ACROSS

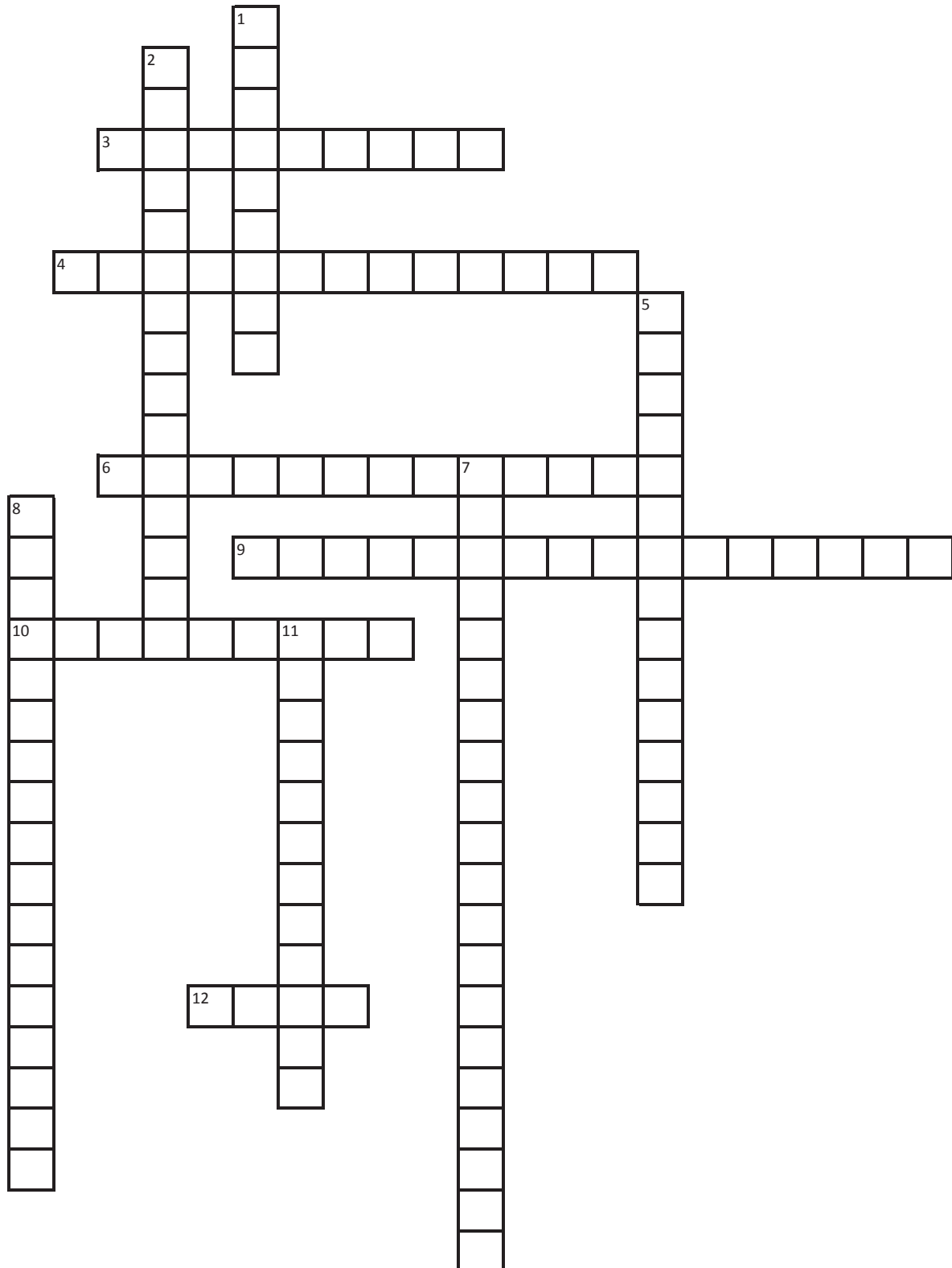
- 3** Planted roofs that help capture and treat rain water before it becomes runoff.
- 4** The material in which plants grow
- 6** A layer in a green roof structure that leaves space for rainwater collect and infiltrate before excess water leaves the roof
- 9** Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves
- 10** A green roof with a shallow layer of growing medium. These green roofs use smaller, more resilient plants, cost less than larger green roofs, and do not hold much weight
- 12** This is an ideal growing environment for many plants composed of living organisms, rock particles, water, air, and organic matter

DOWN

- 1** A green roof that has a thick layer of growing medium, can hold much more weight than extensive green roofs, and can have a larger variety of plants and other structures on top of it
- 2** A surface made out of material that is porous enough to allow water to filter through it. These surface types can vary, but they include soils and groundcovers, permeable paving, etc
- 5** A layer in a green roof structure that prevents water from leaking through the rooftop and into the building
- 7** Design that works to treat stormwater as close to the source as possible to prevent erosion and polluted water sources
- 8** An impenetrable surface that does not allow water to filter through it. It is typically a man-made surface such as asphalt, concrete, etc
- 11** The process by which water on the ground surface enters the soil

Green Roofs Crossword

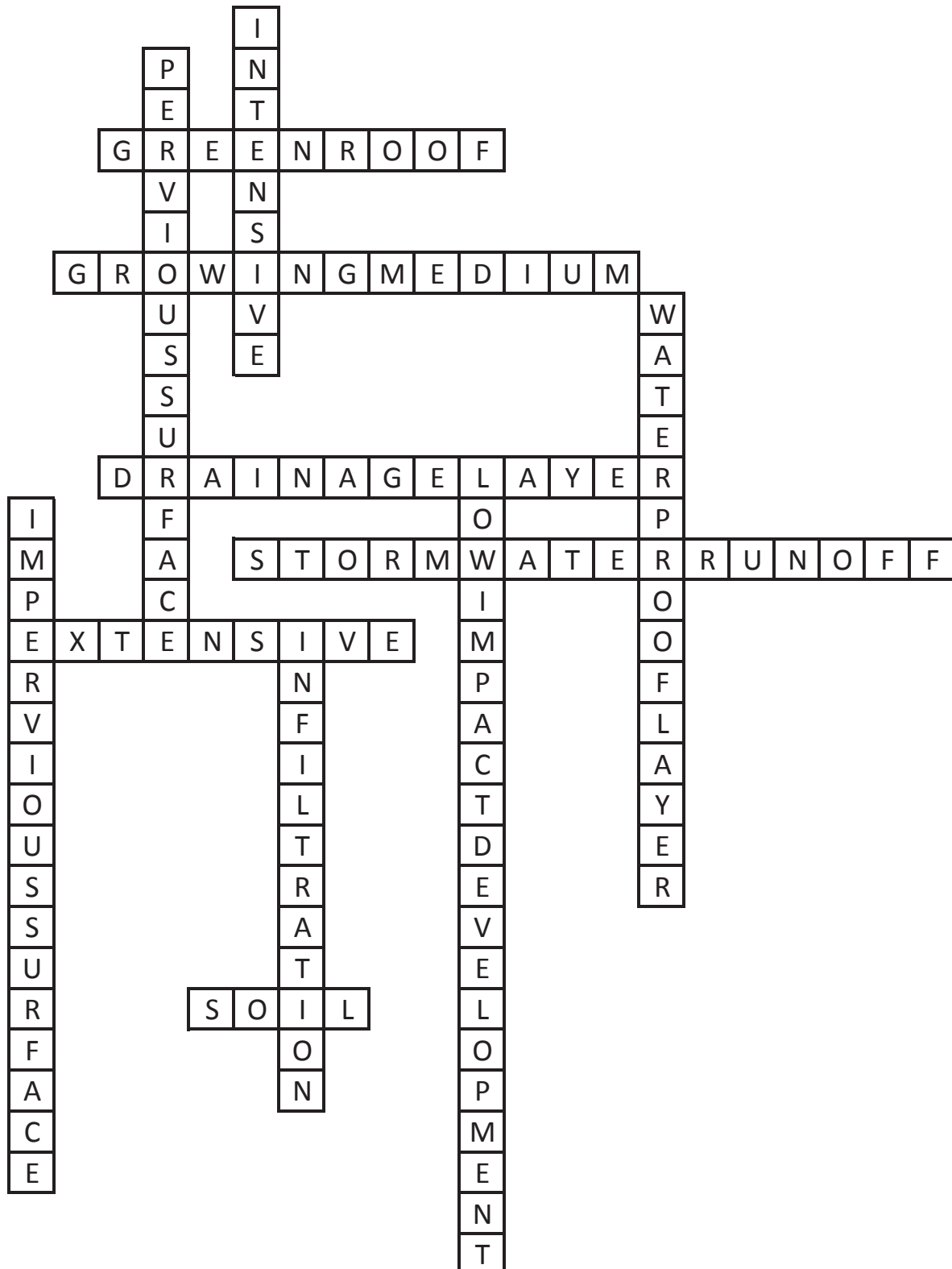
Use the clues provided to fill out the crossword



Stormwater Management

Green Roofs Crossword

Use the clues provided to fill out the crossword



Stormwater Management

Green Roofs Questions

Fill out answers in the space below the questions

Question 1

What is the purpose of a green roof?

Question 2

What are the different layers of a green roof?

Question 3

What were some of the things you drew in your green roof design?

Stormwater Management

Rain Barrels

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of rain barrel function and benefits

3 - 5

MD 5.A.2, MD 7.F.1, 5-ESS3-1, HS-ESS3-4

60 mins



3 - 4 Students

- Handouts (one per student): KWL Chart, Vocabulary, and Questions
- Foam strips, construction paper, glue, tape
- Journal or notebook for recording observations
- Sticky notes
- Colored pencils, markers, or crayons

PROCEDURE

Objectives

- Learn what a rain barrel is and why it's important
- Understand the benefits of a rain barrel
- Learn how to construct and install a rain barrel

Warm Up Activity (5 mins)

Evaluate prior knowledge of rain barrels by completing a “What I Know, What I Want to Know, and What I Learned” (KWL) Chart

Hand out the KWL Chart and allow table groups (3-4 students) about two minutes to come up with as many things they know or wonder about rain barrels. Each table group will share with the class at least two things they discussed.

Suggested questions to ignite brainstorm activity:

1. What is a rain barrel?
2. What is the purpose of a rain barrel?
3. What materials are used to build a rain barrel?
4. Where can a rain barrel be used?

Introductory Activity (7 mins)

Introduce vocabulary and discuss rain barrel elements

Hand out the Rain Barrel Vocabulary Sheet and review it with the students. Use the diagram on the next page to aid understanding.

PROCEDURE CONTINUED

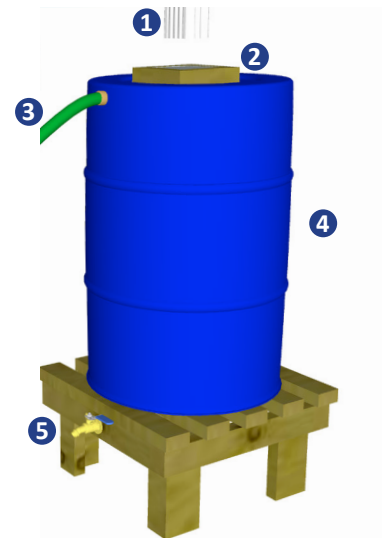
Developmental Activity (8 mins)

Show pictures of different kinds of rain barrels to the students.

Have students analyze what they observe, and record their observations in journals or on paper.

Rain Barrel Components

- ① Downspout
- ② Mosquito Screen
- ③ Sump hose
- ④ Rain barrel
- ⑤ Spigot



Guided Practice Activity (10 mins)

As a group, have students answer the following questions:

1. *What are the benefits of a rain barrel?*
 - a. Reduce stormwater runoff which reduces the amount of sediment and other pollutants that would be washed away with the runoff into storm drains and local streams.
 - b. Healthy water for plants. (Rainwater is naturally soft unlike treated water.)
 - c. Conserve water/groundwater recharge. The slow release of the water allows it to soak into the ground, which supplies water to local streams in between storms.
 - d. Save money; rain barrel water can be used for irrigation.
2. *What are the steps to install a rain barrel?*
 - a. Place bricks, concrete blocks, or pressure treated wood under the barrel to elevate it to create a platform (a higher barrel equals higher water pressure).
 - b. Cut off part of the downspout. Leave space to reattach the downspout end piece.
 - c. Put the rain barrel in place beneath the downspout with the top ring and mosquito screening on top to collect rain water from the roof.
 - d. Reattach the curved down spout end piece to the down spout.
 - e. Connect at least 10 ft of 1 ¼ inch of sump hose to the overflow hole.

PROCEDURE CONTINUED

Independent Task Activity (18 mins)

Have students work in groups to build a rain barrel model

Provide each group with “rain barrel” materials (plastic bottle, foam strips, construction paper, glue and tape). Allow students to construct a rain barrel and its components and then design the outside of their rain barrels. Students can incorporate positive messages into their designs as well as label the different pieces.

Assessment Activity (7 mins)

Have students reflect on their new knowledge of rain barrels

Have students display individual rain barrels and discuss what the students learned. Students should complete the Rain Barrels Questions Sheet then glue or tape the paper into their interactive science journals.

Closing (5 mins)

Summarize the lesson and reiterate the benefits of rain barrels.

Connect discussion back to stormwater and the different types of stormwater BMPs. Have students fill out “What I learned” part of KWL

Extension Activity

Expand knowledge of rain barrels with activities out of the classroom:

- Students can work with parents to build a rain barrel at home
- Students can work together to create a choreographed song and dance about rain barrels

HELPFUL HINTS

Review individual rain barrel components to ensure students understand the rain barrel installation process

Sticky notes may be replaced with regular paper if needed



Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

**Stormwater
Management**

Rain Barrels KWL Sheet

What I Know**What I Want to Know****What I Learned**

**Stormwater
Management****Rain Barrels Vocabulary****Downspout**

A pipe that carries rainwater from a roof to a drain or rain barrel.

Mosquito screen

A mesh netting that prevents mosquitos from breeding in the rain barrel water.

Rain barrel

A barrel that collects and stores rainwater from a roof. It is installed at the base of a downspout coming off the roof.

Spigot

A device used to control the flow of water out of the rain barrel.

Stormwater runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves.

Sump hose

A hose used to direct overflow water out of the rain barrel.

Rain Barrels Questions

Fill out answers in the space below the questions

Question 1

What is the purpose of a rain barrel?

Question 2

What is one benefit of a rain barrel that you learned about today?

Question 3

Name one part of a rain barrel and its purpose.

Stormwater Management

Rain Gardens

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of rain garden function and benefits

3 - 5

MD 1.A.1, MD 5.A.2, MD 7.F.1, 5-ESS3-1, HS-ESS3-4

60 mins



3 - 4 Students

- Handouts (one per student): KWL chart, Vocabulary and Questions
- Journal or paper for recording observations
- Strips of white paper and colored construction paper
- Sticky notes

PROCEDURE

Objectives

- Learn what a rain garden is and why it's important
- Understand the benefits of a rain garden
- Understand the effects of pollution

Warm Up Activity (5 mins)

Evaluate prior knowledge of rain gardens by completing a KWL Chart

Hand out the KWL Chart and allow table groups (3-4 students) about two minutes to come up with as many things they know or wonder about rain gardens. Each table group will share with the class at least two things they discussed.

Suggested questions to ignite brainstorm activity:

1. What is a rain garden?
2. Compare and contrast the differences between a rain garden and a regular garden?
3. Are there different kinds of rain gardens?
4. What is the purpose of a rain garden?

Introductory Activity (5 mins)

Introduce Vocabulary and discuss rain garden elements

Hand out the Rain Garden Vocabulary Sheet and review it with the students. Use diagrams and drawings to aid understanding.

PROCEDURE CONTINUED

Developmental Activity (15 mins)

Take the students on a field trip to observe a local rain garden or show examples of rain gardens virtually

Have students draw what they observe, and record their observations in journals or on paper

Guided Practice Activity (10 mins)

As a group, have students answer the following questions:

1. *What are the benefits of a rain garden?*
 - a. Filter runoff pollution
 - b. Conserve water
 - c. Improve water quality
 - d. Protect rivers and streams
 - e. Create habitat for birds and butterflies
2. *What are pollutants and the dangers they create?*
 - a. Oil and grease from parking lots sediment
 - b. Fertilizers and herbicides from roads, parking lots, and yards
 - c. Can harm or kill fish and other wildlife
3. *Where can a rain garden be built?*
 - a. Residential neighborhoods
 - b. Public gardens and parks
 - c. Street scapes
 - d. Parking lots

Independent Task Activity (15 mins)

Have students complete “Agree or Disagree” activity

Provide each small group with a sentence strip. For about 5 minutes, have the groups discuss and record one benefit they learned about rain gardens on the strip. Pin up the sentence strips around the room.

Provide each group with enough pieces of colored construction paper to leave one response to all the other group’s sentence strips. For 5 minutes, have all students take a gallery walk around the room to read the sentence strips and discuss whether they agree or disagree with the sentences on the strips. Students must give and record reasons why they agree or disagree with the other group’s sentences on the construction paper.

Provide each individual student with a sticky note. For approximately 5 minutes have students take one last gallery walk around the room to read the reasoning statements and write a positive comment on a sticky note and stick it on the construction paper.

PROCEDURE CONTINUED

Assessment Activity (5 mins)

Have students reflect on what they have learned about rain gardens

Have students complete the Rain Gardens Questions Sheet then glue or tape the paper into their interactive science journals.

Closing (5 mins)

Summarize the lesson and reiterate the benefits of rain gardens.

Connect discussion back to stormwater and the different types of stormwater BMPs

Extension Activity

Expand knowledge of rain gardens with activities out of the classroom

- Students can research rain garden plants and materials
- Students can take a field trip to visit local rain gardens
- Students can research how to build and maintain a rain garden
- Students can create an inventory of rain gardens in their neighborhood

HELPFUL HINTS

If class size is too large or resources limited, the independent activity can be completed in small groups

The entire lesson plan can be completed at the rain garden location



Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

**Stormwater
Management**

Rain Gardens KWL Sheet

What I Know

What I Want to Know

What I Learned

**Stormwater
Management****Rain Gardens Vocabulary****Rain garden**

A man-made depression that is planted with deep-rooted native plants and grasses that infiltrates and cleans storm-water runoff.

Infiltration

The process by which water on the ground surface enters the soil.

Stormwater runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves.

Pollution

Substances that make land, water, and air dirty and unsafe or suitable to use.

Rain Gardens Questions

Fill out answers in the space below the questions

Question 1

What is the purpose of a rain garden?

Question 2

What is one benefit of a rain garden that you learned about today?

Question 3

Where could a rain garden be built?

Stormwater Management

Rain Garden Plants

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of rain garden plants and benefits

9 - 12

MD 1.A.1, MD 5.A.2, MD 7.A.1, 5-ESS3-1, MS-ETS1-3, HS-ESS3-4,

90 mins



2 - 3 Students

- Handouts (one per student): **Vocabulary, Questions, and Plant chart**
- Access to a rain garden that can be revisited every year
- List of plants originally planted in the rain garden
- Original planting map for the rain garden
- Blank rain garden map for students

PROCEDURE

Objectives

- Observe and record different plant and animal species in a rain garden
- Compare observations with those from previous years
- Learn about native and invasive species

Warm Up Activity

Evaluate prior knowledge through class discussion

Ask students: What are some plants typically found in your area?

Answers will vary. The purpose is to get a conversation going about common plants found in your area and plant diversity in the landscape. Discuss plants they see in their yards, on the school grounds, etc.

Introductory Activity

Talk about endemic plants, invasive plants, and well-adapted plants and how they affect our ecosystems

Hand out and review rain garden plant vocabulary terms.

Endemic or native plants are beneficial to the environment because they already have their own purpose and niche that works with the other native species to keep a productive, working ecosystem with diversity and growth.

PROCEDURE CONTINUED

Introductory Activity (continued)

Well-adapted plants that are not native are not as beneficial, but they are not harmful to the ecosystem and can have some benefits like aesthetics or helping other species. Invasive species take space and resources from other species, harm or overwhelm other species, and promote monocultures, or lack of diversity in the landscape.



Non-native, invasive kudzu vine covering other species



Native rain garden species

Developmental Activity

Introduce the plants that were originally planted in the rain garden as well as any new species that can be found.

Split students into groups. Review plant characteristics with students. Make sure to note that each plant has aesthetic features (flowers, fall color, fruits, or wildlife attraction) as well as preferences on the light it gets, soil it grows in, and water it needs. Note the fact that some of these plant characteristics may not be visible depending on the time of year.

Make sure to emphasize the characteristics that make these plants ideal for a rain garden. They are drought and flood tolerant, so whether the rain garden is overflowing or parched, the plant will survive. They also have deep, established roots which are ideal for absorbing as much water as possible from the soil.

Guided Practice Activity

Walk around the rain garden and have students observe the different plant and animal species they see.

Hand out a blank map of your rain garden and ask students to use different colors or symbols to draw each plant species they find on the map. Have students record species information on the **plants chart**. They should work in groups to try to find and identify as many plants on the list as possible and record any additional plants they come across. Students may draw or take pictures of what they observe.

**With teacher permission, students can remove invasive species in the rain garden. Students should try to identify the plant before removing.*

PROCEDURE CONTINUED

Independent Task Activity

Have students work together to compare the observations from the past years with their own.

Back in the classroom, pass out observations from previous years. This can include maps, notes, photos, etc. Students should work in groups to compare their findings with past results and answer the Rain Garden Plants Questions Sheet

Assessment Activity

Have students discuss their analyses with the class and share examples of observations they made that differ from those from previous years.

Answers will vary. Students should share an observational difference, then explain why the change occurred. New species could be present because of lack of maintenance, invasive plant characteristics, wind or animal seed dispersal etc. If older plants aren't doing well, it could be related to light, water, soil conditions, pests or disease. Make sure to collect all observation notes and maps for future students to make comparisons.

Have students form a hypothesis as to how the plants will do in the future, or what the garden will look like in a few years. Answers will vary, but the purpose is to get the students familiar with plant characteristics and habits.

Closing

Summarize the lesson and reiterate the impact of endemic species vs. invasive species. Discuss how plants are a vital part of a rain garden and stormwater management.

Discuss which plants (if any) the students think might be invasive. Plants are an important part of a rain garden because they aid in filtering the stormwater that moves through the site. They also use that water to grow and then cause evapotranspiration, sending that water back into the water cycle.

Extension Activity

Expand knowledge of plants with activities out of the classroom.

- Students can identify and research the invasive species found in the rain garden, then write a short report on the plant's nativity, habit and other characteristics. They can research endemic plants that are similar and could replace the invasive species.
- Students can research the concept of plant diversity including Shannon's Diversity Index and write a small report on how it works (number of species and evenness of abundance) and why diversity is important. They should include their own thoughts about the diversity of plants found in the rain garden.

PROCEDURE CONTINUED

HELPFUL HINTS

This lesson can be done twice during the academic year: once in the fall and once in the spring. That way students can observe the changes in the plants at different points during the year. Make sure to teach the lesson around the same time(s) each year for accurate data.

Before removing a plant, make sure it is invasive and also not poison ivy.

Identifying plants will get easier every year that you teach the lesson. Students will also get the hang of identifying plants by their different characteristics.



Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

Stormwater Management

Rain Garden Plants Vocab

Berm

A raised bank, typically used to control where water is contained or flowing.

Bioretention

The process in which contaminants and sedimentation are removed from stormwater runoff by holding and infiltrating water into the ground.

Endemic

Native plants that have developed, occur naturally, or existed for many years in an area

Invasive

Non-native plants that have the ability to thrive and spread aggressively outside their natural range. They threat to overtake other plant species.

Low Impact Development (LID)

Design that works to treat stormwater as close to the source as possible to prevent erosion and polluted water sources.

Habit

Refers to the form or shape the plant is growing in. It can also be as simple as identifying if it is a tree, shrub, vine, groundcover, perennial, etc.

Infiltration

The process by which water on the ground surface enters the soil.

Non-native plants

Plants that have been introduced to a new area different from their native range, either purposefully or accidentally. They are not necessarily harmful to other plants in their native habitats, and can sometimes fill a certain need better than native plants.

Organic soil mixture

Soil consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms among other types of soil.

Rain Garden

A planted depression that infiltrates and cleans stormwater runoff.

Transpiration

The process in which water is carried through plants and is released through the leaves into the atmosphere as vapor. It is essentially the evaporation of water from a plant.

Stormwater Runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves.

Swale

A graded landscape feature appearing as a linear, shallow channel. Usually vegetated to help move and filter stormwater at a controlled rate.

Wetland

A land area that is saturated with water, either permanently or temporarily.

Stormwater Management		Rain Garden Plants Chart	
Species	Location	Tally	Notes

Rain Garden Plants Questions

Fill out answers in the space below the questions

Question 1

How many plants from the list did you identify? Which plants were missing or unidentifiable?

Question 2

Did you find any exotic species? Draw or describe these plants.

Question 3

Compare your map with one from another year. What year is it from? What are the similarities and differences between the two maps?

Question 4

What do you think are the differences between the maps/why do you think the changes occurred?

Stormwater Management

Soils

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will gain an understanding of soils and sampling techniques

9 - 12

MD 1.A.1, MD 1.A.4, MD 1.A.5, MD 2.A.1, MD 3.A.1, 3-5-ETS1-3, MS-ETS1-3, MS-ETS1-4

90 mins



3 - 6 Students

- Handouts: Vocabulary Sheet, Soil Textural Triangle, Reflection Questions [one per student]
- 1 Soil core sampler
- For Percolation test: Large coffee cans with the top and bottom removed (min. 6" diameter); Rulers; Small Shovels; buckets of water
- For Analysis: Trays or plastic tubs for soil samples; pH testing kit

PROCEDURE

Objectives

- Learn to take a soil core sample
- Understand percolation and absorbency rates of different soil types
- Observe, analyze and compare soil samples

Warm Up Activity

Evaluate prior knowledge through journal questions.

1. What are the different soil types?

Answers will vary. There are different labels used to define soil type. Soils can be clay, sand, silt, loam, or any combination of the four. (Soil can also be chalky, peaty, organic, acidic, or alkaline, but sand, clay silt, and loam are the most relevant to this activity). After discussing the answers, make sure students get a general knowledge of the four soil types.

2. What are the different components of soil?

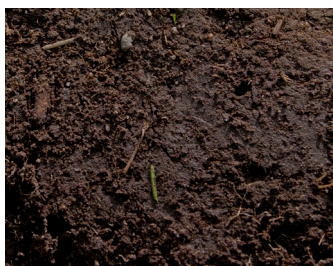
Answers will vary. Discuss the different things that are found in soil and what soil is made up of. Answers can include: Minerals (sand, silt, clay), air, water, and organic matter (humus). Decaying animals or plants, live insects, rocks, and roots can also be found in soil.

PROCEDURE CONTINUED

Introductory Activity

Review soil types and soil vocabulary terms

Introduce the different soil types and hand out **vocabulary sheet**. Use images for reference.



Loam



Clay



Sand

Developmental Activity

Introduce the soil textural triangle

If computers are available, have students visit the NRCS Soil Texture Calculator website (below) or distribute the soil textural triangle handout.

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs14p2_054167

The triangle shows the 12 soil classes defined by the USDA. The triangle is used to determine the type of soil you have. This is important to know to determine which types of plants will grow well, estimate the percolation rates of the soil, etc.

Determine the percentages of clay, silt, and sand in the soil. Starting with sand, find the percentage on the corresponding side of the triangle. Do the same with clay, then silt. Follow the lines that correspond with each percentage into the triangle to find the point at which they intersect. Whichever labeled section of the triangle the intersection is in, is the soil type (See Soil Textural Triangle).

Guided Practice Activity

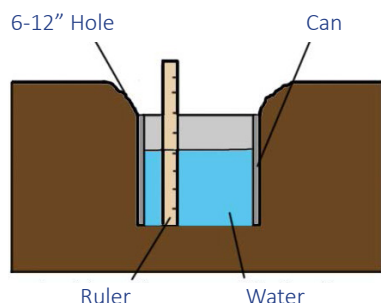
Start percolation tests in a bioretention cell, and in another area outside the cell. Take soil core samples from the same locations.

A percolation test is a test to determine the absorption rate of soil. Typically, a percolation test is used to determine how much space is needed to infiltrate a certain amount of water, however, this activity is just about comparing the percolation rates of two locations and analyzing the difference.

Guided Practice Activity (continued)

PROCEDURE CONTINUED

Each group should do their own percolation test with teacher supervision and assistance. Make sure to record how much water is used for each test and use the same amount for all tests.



How to Do a Percolation Test

1. Find a flat location within the desired area
2. Dig a 6" - 12" hole
3. Place a large hollow can with no top or bottom in the hole so the bottom of the can digs into the soil
4. Place a ruler in the can to take measurements
5. Fill the can with water up to the desired level
6. Record the time it takes for the water to infiltrate into the ground
7. Convert this rate to a desired ratio (min/cm, etc)

A soil core sample is done with a soil probe or soil core sampler. Purchasing a soil core sampler is probably the cheapest and easiest option. An ideal tool will have a cut-out so the students can observe the different layers of soil while they are intact.

The teacher should take one soil core sample for each group while they observe. Each group will have their own soil to examine.



How to Take a Soil Core Sample

1. Gently brush aside any mulch or debris
2. Push a soil core sampler or probe into the ground as deep as possible (depth will vary based on the tool)
3. Slowly lift the probe back up out of the ground to remove the core

Independent Task Activity

Have students collect data from all soil core samples and percolation tests

Students will draw what they see in the soil probes, then separate out types of soil from the core samples into tubs or trays.

Demonstrate first, then have them perform a "ribbon test" to help determine the type of soil they are examining.

PROCEDURE CONTINUED

Independent Task Activity (continued)

They should feel through the soil and note anything they find. Also have them compare absorption rates from both percolation tests. Students should record their observations and analyze the differences between both percolation tests and soil core samples (See **Observation Questions Worksheet**). Students can also record the pH of the soil core samples using the pH testing kit. Make sure students wash their hands after touching the soil.



How to Complete a Ribbon Test

1. Knead a small, wet clump of soil in your hand.
2. Slowly form a “ribbon” by working the ball through your thumb and pointer finger.
3. Analyze the result:
 - a. If the ribbon breaks before reaching 1 inch in length (or doesn’t form at all), and also feels course, then you have sandy soil
 - b. If it does not feel course, you have silt
 - c. If the ribbon breaks between one and two inches you probably have a loam mixture
 - d. If the ribbon is over two inches before breaking then you have clay

Assessment Activity

Discuss data as a class and have students write a journal entry for homework describing and analyzing the results

Be sure to discuss which soil infiltrated the fastest and why:

- a. The soil from the bioretention cell should infiltrate faster because it was mixed and brought in specifically for its fast absorption rate, making the rain garden highly effective.
- b. Sandy soil will infiltrate the fastest because the particles are larger and it is porous, leaving more space for air and water to travel through.
- c. Clay soil is not very porous and it has very small particles, making it very difficult for water to seep in.

Ask students what type of soil is found outside of the bioretention cell (they can use their soil textural triangle as a guide). Ask students to share any other observations they made of the soil cores or percolation tests. Answers will vary.

PROCEDURE CONTINUED

Closing

Summarize the lesson and discuss why soil is an important aspect of a rain garden

Rain gardens are built to capture, infiltrate, and clean stormwater before it makes its way into streams and larger bodies of water. The type of soil in a rain garden can determine its effectiveness. The soil must be porous and have a high infiltration rate in addition to supporting the plant life in the garden. That way water can infiltrate quickly so there is minimum overflow and no standing water.

Extension Activity

Expand knowledge of soils with activities out of the classroom:

- Students can dig up a soil sample at home or elsewhere (with permission) and analyze it using the soil textural triangle and the ribbon test. They can compare that soil to the soil in the rain garden.
- Students can also do a percolation test at home (with permission) to compare the different absorption rates of the soils.

HELPFUL HINTS

Do a soil core sample for each group individually while the group members watch closely and observe. Let each group look at the soil in the tube and take a picture before dumping it in the tub or tray.

While doing a percolation test, if the water drains too quickly to time it, it just means the soil has high sand or silt content. Be sure to record how much water you poured in the hole to compare to other tests.



Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

Soils Vocabulary

Bedrock	Consolidated rock underlying the surface of the earth
Capillary Action	The ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity
Clay	A soil that contains a high percentage of fine particles and colloidal substance and becomes sticky when wet
Erosion	The slow removal and wearing away of soil on the earth's surface by water, ice, wind, etc.
Humus	Organic material that forms in soil when plant and animal matter decays
Loam	A fertile soil of clay and sand containing humus
Organic Soil Mixture	Soil consisting of plant and animal residues at various stages of decomposition; cells and tissues of soil organisms among other types of soil
Percolation	Passing through a porous material; filtering
Permeability	The ability of rock or soil to allow water to flow through it
pH Level	A number that is a measure of how acidic or basic a substance is. The lower the pH number is, the more acidic a substance is; the higher a pH number is, the more basic a substance is.
Porosity	The amount of space between the particles that make up a rock
Sand	A naturally occurring granular material composed of finely divided rock and mineral particles
Silt	Granular material of a size somewhere between sand and clay
Soil Core Sampling	Collecting undisturbed soil core samples for soil profiling and environmental investigations
Subsoil	The layer of soil under the topsoil on the surface of the ground. Like topsoil it is composed of a variable mixture of small particles such as sand, silt and/or clay, but it lacks the organic matter and humus content of topsoil
Top Soil	The surface layer of soil, which is usually richer in organic matter than the subsoil is. Fertile topsoil is composed of living organisms, rock particles, water, air, and organic matter, such as dead or decomposing organisms.

Soils Questions

Fill out answers in the space below the questions

Question 1

Draw what you see in the soil core samplers. Include and label different soil layers (if any) and textures.

Question 2

What colors, textures, and sizes of soil particles did you find in the soil? Record your findings here.

Question 3

What are the differences between your observations of the soil in the bioretention cell and the soil from outside the cell?

Question 3

What were the results from the percolation test? Do these results make sense? Why or why not?

Stormwater Management

Permeable Pavement

Overview

Students will gain an understanding of permeable surfaces and how to calculate runoff storage.

Grade Level

9 - 12

Science Standards

MD 1.A.1, MD 1.B.1, MD 2.A.1, MD 5.A.1, MD 5.A.2, MD 7.A.1, 3-ESS3-1, 4-ESS2-1, 4-ESS3-2, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, HS-ESS3-4

Time

90 mins

Teacher Difficulty



Group Size

3 - 4 Students

Materials

- Handouts (one per students): Vocabulary Sheet and Questions sheet
- Measuring things
- Journal or paper for recording observations

PROCEDURE

Objectives

- Learn about permeable pavement types
- Understand the benefits of permeable surfaces
- Use calculations to determine storage volumes and depths

Warm Up Activity

Evaluate prior knowledge of permeable pavement with class discussion

Suggested questions to ignite brainstorm activity:

1. What makes a surface permeable?
2. Compare and contrast the differences between impervious and pervious surfaces.
3. What problems can impervious surfaces cause?
3. Are there different kinds of permeable surfaces?
4. What is the purpose of permeable surfaces?

Introductory Activity

Introduce vocabulary and discuss permeable pavement/paver elements

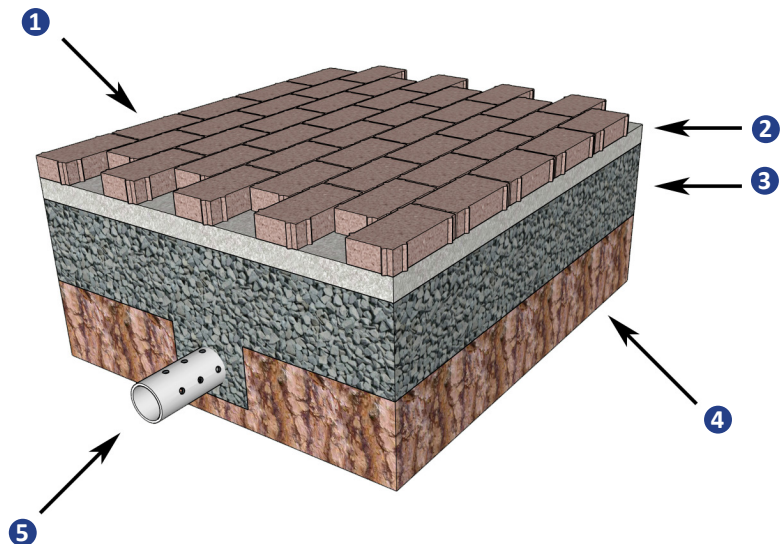
Hand out the Permeable Pavers Vocabulary Sheet and review it with the students. Use the diagram on the next page to aid understanding.

PROCEDURE CONTINUED

Introductory Activity (continued)

Be sure to review the different layers of permeable pavement and the stormwater runoff resevoir.

Permeable Pavement Detail



Permeable Pavement Components

- ① Pavers
- ② Bedding Course
- ③ Reservoir Course (porous stone)
- ④ Uncompacted Soil
- ⑤ Underdrain

After reviewing vocabulary and the different components of permeable pavement ask students:

1. Why is it good to store stormwater in a resevoir layer?

Runoff from storm events carries suspended solids and pollutants. Permeable pavement resevoirs will remove those solids and pollutants from the runoff as it passes through the stone in the resevoir. Storing runoff also prevents further pollutants and stormwater from reaching the watershed.

2. Why do you need an underdrain?

Underdrains slowly drain the collected runoff out of the resevoir layer. Draining the filtered sotrmwater allows for the resevoir to be prepared for the next rain event.

PROCEDURE CONTINUED

Developmental Activity

Introduce the variables used to calculate volume and depth

Explain the following equation to students and work through the example to determine the volume of a parking lot's storage layer. Students should work through the example on their Questions sheet.

CALCULATE STORAGE VOLUME OF THE RESEVOIR LAYER

$$\begin{array}{ccccccc} V_{storage} & = & D_{resevoir} & \times & P_{resevoir} & \times & A_{surface} \\ (ft^3) & & (ft) & & (0-0.99) & & (ft^2) \end{array}$$

Where:

$$\begin{array}{ll} V_{storage} & = \text{total volume of the stormwater storage} \\ D_{resevoir} & = \text{depth of the resevoir layer of stone} \\ P_{resevoir} & = \text{porosity of the resevoir stone (percent air space)} \\ A_{surface} & = \text{total surface area of permeable paving} \end{array}$$

As variables:

$$V_s = D_r \times P_r \times A_s$$

EXAMPLE 1:

If an 80 ft by 20 ft parking lot has a reservoir layer that is one ft deep, what is its storage volume?

First, find the necessary variables:

$$A_s = 80 \text{ ft} \times 20 \text{ ft} = 2400 \text{ ft}^2$$

$$D_r = 1 \text{ ft}$$

$$P_r = 0.35$$

(Assume $P_r = 0.35$ for all problems)

Then, plug the variables into the equation:

$$V_s = 1 \text{ ft} \times 0.35 \times 2400 \text{ ft}^2$$

Finally, multiply to solve for the storage volume:

$$V_s = 840 \text{ ft}^3$$

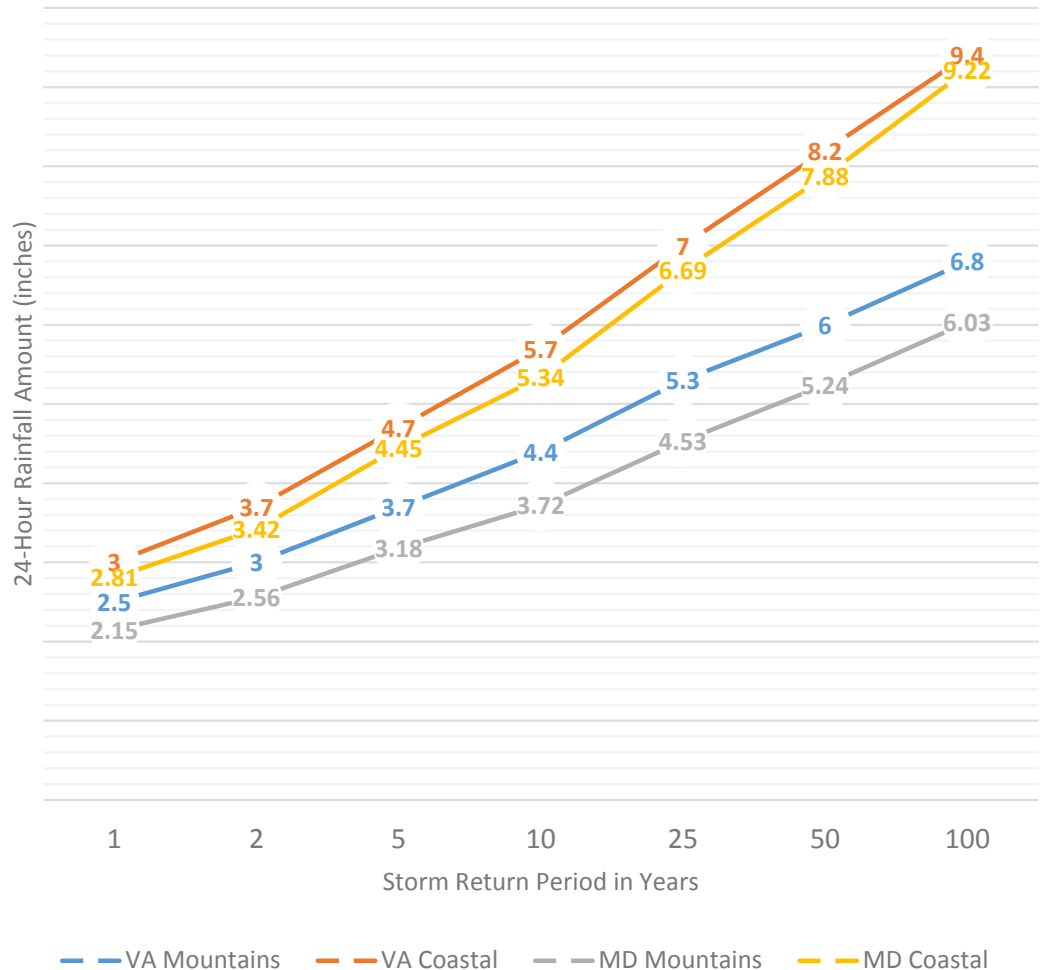
PROCEDURE CONTINUED

Guided Practice Activity

Introduce the 24 hour rainfall chart to students

The rain fall chart shows the amount of rain (in inches) that occurs in a 24 hour period for different types of storms. The storm return periods are an estimation of how likely a storm is to occur annually. A return period of 100 means that a storm of that size is likely only to return once everyone 100 years. The chart below shows the rainfall amounts in Virginia and Maryland.

24 HOUR RAINFALL TOTALS (INCHES)



After discussing the chart, explain how permeable pavement systems must be designed to store different storm sizes.

Have students explain the relationship of the reservoir depth to a permeable pavement system's storage volume capacity. That is, the deeper the reservoir, the more storage volume.

PROCEDURE CONTINUED

Guided Practice Activity (continued)

Using the equation and example below, work as a class to determine if the parking lot from example 1 can store a 100 year storm. Students should work through the example on their questions work sheet.

CALCULATE VOLUME OF A STORM IN A CERTAIN AREA

$$V_{storm} = T_{rainfall} \times A_{surface}$$

(ft^3) $(in/12)$ (ft^2)

Where:

V_{storm} = total volume of the storm

$T_{rainfall}$ = total rainfall in inches

$A_{surface}$ = total surface area of permeable paving

As variables:

$$V_{storm} = T_r \times A_s$$

EXAMPLE 2:

What is the volume of rain that will be distributed to an 80 ft by 20 ft parking lot if the total rainfall is 7 inches?

First, find the necessary variables:

$$\begin{aligned} T_r &= 7 \text{ in} \\ &= 7/12 \text{ in} \\ &= .583 \text{ ft} \end{aligned}$$

$$\begin{aligned} A_s &= 80 \text{ ft} \times 20 \text{ ft} \\ &= 2400 \text{ ft}^2 \end{aligned}$$

Then, plug the variables into the equation:

$$V_{storm} = .583 \text{ ft} \times 2400 \text{ ft}^2$$

Finally, multiply to solve for the total storm volume:

$$V_{storm} = 1,399.2 \text{ ft}^3$$

Discuss with students: Knowing the storage volume of the parking lot, will the reservoir layer be able to store a 7 in storm?

Answer: NO. How deep would the reservoir need to be to be able to store all of the rainwater?

PROCEDURE CONTINUED

Independent Task Activity

Calculate storage volume of your school parking lot

Have students measure a permeable paved area on school property (if none on site, you may use any paved area). If possible, find the actual reservoir depth for the permeable parking lot. If not, assign a hypothetical depth. Once all variables are collected, students should use the equations from the edamples to calculate storage volume needs for that parking lot.

Assessment Activity

Have students reflect on their new permeable pavement knowledge

Students should complete the rest of the question sheet in class or take it home for individual homework.

Closing

Summarize the lesson and reiterate the benefits of permeable pavement.

Connect discussion back to stormwater and the different types of stormwater BMPs

Extension Activity

Expand knowledge of permeable pavement with activities out of the classroom

- Students can calculate the volume of different sized rain events on paved areas at their home
- Students can research areas in their city that use permeable pavement techniques

HELPFUL HINTS

The calculations can also be used to help students refresh knowledge of conversions between feet and inches, as well as cubic feet, to cubic inches, to gallons.



Landscape Architecture
DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE

Stormwater Management

Perm. Pavement Vocab

Groundwater

Water that collects or flows underground in the soil, pores, or crevices of rocks

Infiltration

The process by which water on the ground surface enters the soil

Low Impact Development (LID)

Design that works to treat stormwater as close to the source as possible to prevent erosion and polluted water sources

Permeable Pavers

A hardscape surface that allows water to infiltrate through it into the ground or an underdrain. These include porous asphalt, permeable pavers, pervious concrete, and aggregate

Porosity

Also known as 'void fraction,' it is the measure of the empty spaces in a material. (resevoir layer porosity)

Rainfall depth

The total amount of rain falling in a given period, measured in inches

Resevoir Layer

The storage area underneath a permeable surface that collects and stores surface runoff. It is usually full of No. 57 or No. 2 stone.

Storage Volume

The amount of water a resevoir layer can hold based on size and the porosity of the stone it contains.

Storm Return Period

An estimation of how likely a type of storm is to occur in a given amount of time. A return period of 100 means that a storm of that size is likely only to return once every 100 years.

Stormwater Runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves

Underdrain

Usually a perforated pipe underlaying a porous gravel material. Its purpose is to allow water to slowly drain out of the reservoir so it is ready for the next storm.

Stormwater Management

Perm. Pavement Questions

Use the equations and the example problems to answer questions in the space provided.

Calculating Storage Volume

To calculate the storage volume of a permeable pavement's reservoir area, three variables need to be found: The depth of the reservoir layer (D_r), the porosity of reservoir layer (P_r), and the area of the permeable surface (A_s). Multiplying these three variables results in the Storage Volume (V_s).

$$V_{\text{storage}} = D_{\text{reservoir}} \times P_{\text{reservoir}} \times A_{\text{surface}}$$

$(\text{ft}^3) \qquad (\text{ft}) \qquad (0-0.99) \qquad (\text{ft}^2)$

As variables:

$$V_s = D_r \times P_r \times A_s$$

(Assume $P_r = 0.35$ for all problems)

Calculating Rainfall Volume

Multiplying the rainfall totals (T_r) in inches and the area of a given surface (A_s) results in the Storm Volume (V_{storm}).

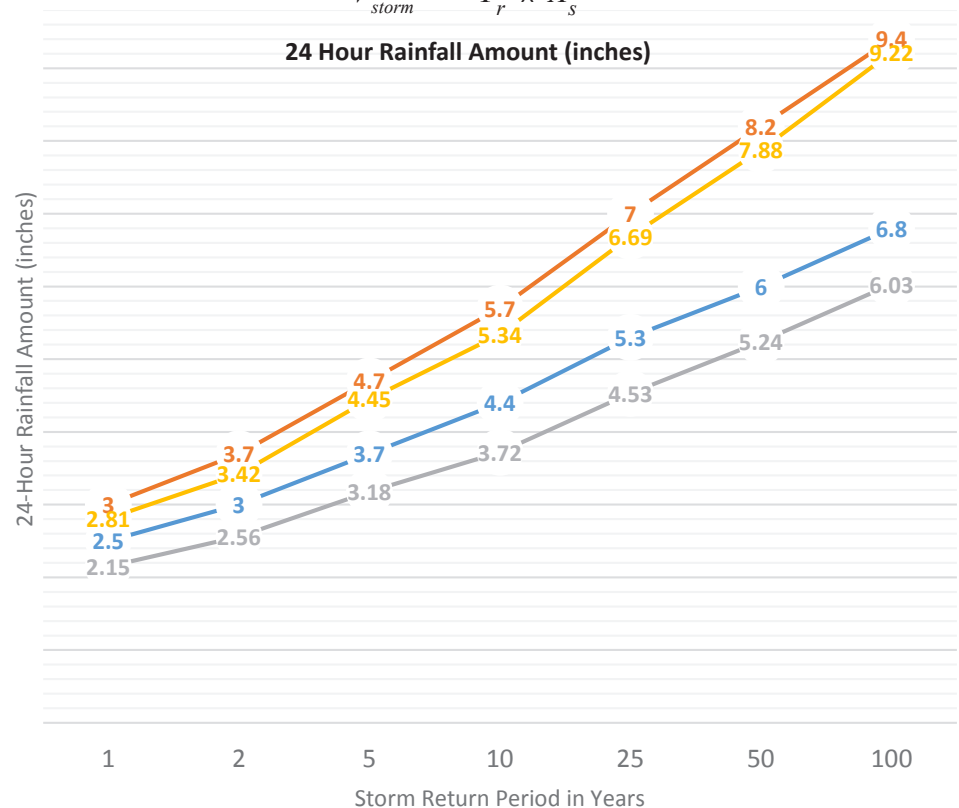
$$V_{\text{storm}} = T_{\text{rainfall}} \times A_{\text{surface}}$$

$(\text{ft}^3) \qquad (\text{in}/12) \qquad (\text{ft}^2)$

As variables:

$$V_{\text{storm}} = T_r \times A_s$$

Rainfall Amount Chart



Example 1

If an 80 ft by 20 ft parking lot has a reservoir layer that is one ft deep, what is its storage volume?

Example 2

What is the volume of rain that will be collected on the 80 ft by 20 ft parking lot if the total rainfall is 7 inches?

Question 1

What is the highest level of storm return that a 12 x 30 ft permeable driveway in Maryland's mountains would be able to store if it has a 1.5 ft deep resevoir and uses No. 57 stone ($P_r = 0.35$)?

Question 2

What does the minimum depth of a resevoir layer need to be for a 30 ft by 20 ft patio to be able to store a 5 year storm on the Virginia coast?

Stormwater Management

Hydrology

Overview

Grade Level

Science Standards

Time

Teacher Difficulty

Group Size

Materials

Students will learn about human interactions with runoff and infiltration

9 -12

MD 1.A.1, MD 1.A.4, MD 1.A.5, MD 2.A.1, MD 3.A.1, MD 5.A.1, MD 5.A.2, 3-ESS3-1, 3-5-ETS1-2, 3-5-ETS1-3, MS-ESS2-4, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4, HS-ESS3-4, HS-ETS1-3

90 mins



3 - 6 Students

- Handouts (one per student): Vocabulary, Water Cycle Diagram, Hydrology Questionnaire, Infiltration Experiment Instructions

PROCEDURE

Student Objectives

- Learn how to build a model for a science experiment
- Understand how different surfaces and soils affect the amount of runoff that results from a rain event
- Evaluate human impacts on natural processes, such as stormwater

Warm Up Activity

Evaluate prior knowledge through class discussion

In what ways do humans interact with the water that cycles through our environment? What are the outcomes?

Answers will vary. Humans use water in their everyday lives and have countless interactions with the water cycle.

Answers could include uses like pumping water into homes and buildings, watering a garden, swimming in a lake. Get students talking about some of the negative impacts humans have on the water cycle. Talk about how human development means more impervious surfaces in the landscape and how toxins and pollutants from our cars, homes, and lawns are carried into streams by stormwater. Impervious surfaces increase runoff and pollution and prevents infiltration into the ground.

Introduce LID practices and how they can decrease runoff.

PROCEDURE CONTINUED

Introductory Activity

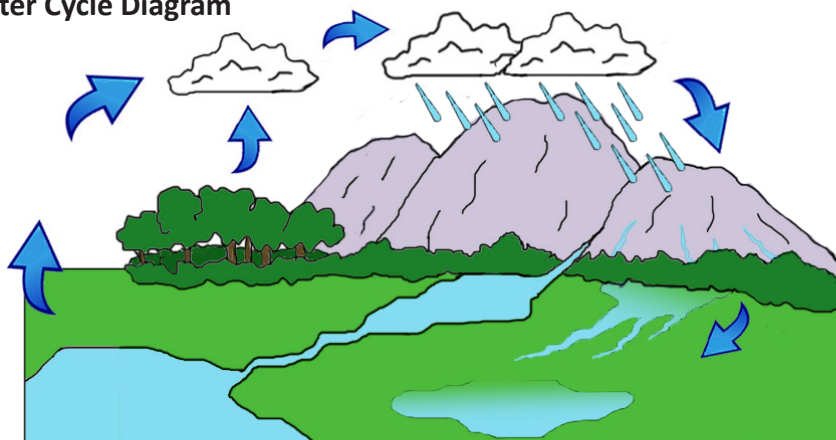
Review hydrologic cycle and hydrology vocabulary terms

Hand out the **Hydrology Vocabulary and Water Cycle Handouts**. Have students work individually or in pairs to fill out as many water cycle processes on their sheet as possible. Students can use the vocabulary sheet as a word bank.

As a group, go over the correct answers. Discuss how the hydrologic cycle “starts” with the evaporation of water from the surface of the ocean or other bodies of water. As the water rises, it becomes water vapor. Once high enough, condensation occurs, and the water falls back down to earth as precipitation. Once the water reaches the ground, one of three processes may occur; some of the water may evaporate back into the atmosphere, some may penetrate the earth’s surface and become groundwater, and some will travel across the ground as runoff. Groundwater either seeps into oceans, rivers, or lakes, or is released back into the atmosphere through transpiration from plants. The water that remains on the earth’s surface flows over the land as runoff into lakes, rivers, and streams and is carried back to the oceans, where the cycle starts over.

This should be review for high school students but make sure to include vocabulary terms like stormwater, groundwater, surface runoff and infiltration.

Water Cycle Diagram



Developmental Activity

Show students a sample model and demonstrate test steps

Using a pre-made model for reference, go through the steps to build each model. Explain the importance of each material used and what it represents in the models: Soils, Impervious surfaces, Trees, and Buildings. Explain the different variables and LID options.

PROCEDURE CONTINUED

Developmental Activity (continued)

After reviewing steps to build a model, hand out experiment instructions to students.

Assign groups, and ask students to create hypotheses for their assigned materials. Briefly review the scientific method with students if necessary.

For best results, keep group sizes at 3-4 students. Depending on the size of the class, this experiment can be conducted with three or six groups. See the charts below for assigning groups.

Assignments for Three Groups		Soil		
		Sand	Loam	Clay
Pavement	Impervious	Group 1	Group 2	Group 3
	Permeable	Group 1	Group 2	Group 3

Assignments for Six Groups		Soil		
		Sand	Loam	Clay
Pavement	Impervious	Group 1	Group 2	Group 3
	Permeable	Group 4	Group 5	Group 6

Guided Practice Activity

Run through experiment with students

Using the pre-made model, have one student from each group participate in the practice run through in front of the class. Review the importance of consistency in the scientific method.

Independent Task Activity

Students build models and conduct experiments

Have groups build their models and conduct their experiments for each type of infiltration variable they are assigned. Be sure that all groups use the same amount of water for each test, as well as pour water into the trays at a consistent rate.

Ensure that everyone records data for each variable.

PROCEDURE CONTINUED

Assessment Activity

Discuss recorded data with the class and compare results

Students should share data with the class and compare results. Have students fill out a chart on the board (similar to the group assignment chart) with the amount of water collected for each model.

Complete the **Hydrology Questions Sheet** at this time or as homework to be turned in later.

Closing

Summarize the results and connect to future lessons

Discuss connections to landscape architecture, stormwater best management practices (BMPs), and soils.

Extension Activity

Expand knowledge of hydrology with activities out of the classroom:

- Students can draw a map of their own yards or a site in town and observe and record where the water flows on the site and what materials are present. Students can hypothesize which materials around their home promote or reduce infiltration
- Students can visualize pollution as they run the test on their models by putting a few drops of food dye on their parking lots before pouring the water. That way they can see the food dye “pollution” caught in their cups at the end, symbolizing polluted runoff.

HELPFUL HINTS

Instead of purchasing soil, find loam and clay on school property to use for the experiment. Students can conduct a test to verify that the soils are loam or clay and collect the soils in large buckets.



Landscape Architecture
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Stormwater Management

Hydrology Vocabulary

Atmosphere

The gaseous mass surrounding the earth

Condensation

The process by which gas cools and becomes liquid

Groundwater

Water that collects or flows underground in the soil, pores, or crevices of rocks

Hydrology

The study of earth's water, including the movement in relation to land

Infiltration

The process by which water on the ground surface enters the soil.

Low Impact Development (LID)

Design that works to treat stormwater as close to where it falls as possible to prevent erosion and pollution.

Precipitation

Any product of the condensation of atmospheric water vapor that falls under gravity; including rain, snow, sleet, and hail

Stormwater Runoff

Water that originates during precipitation events and flows over the land. It can pick up sediment, pollutants, and debris as it moves

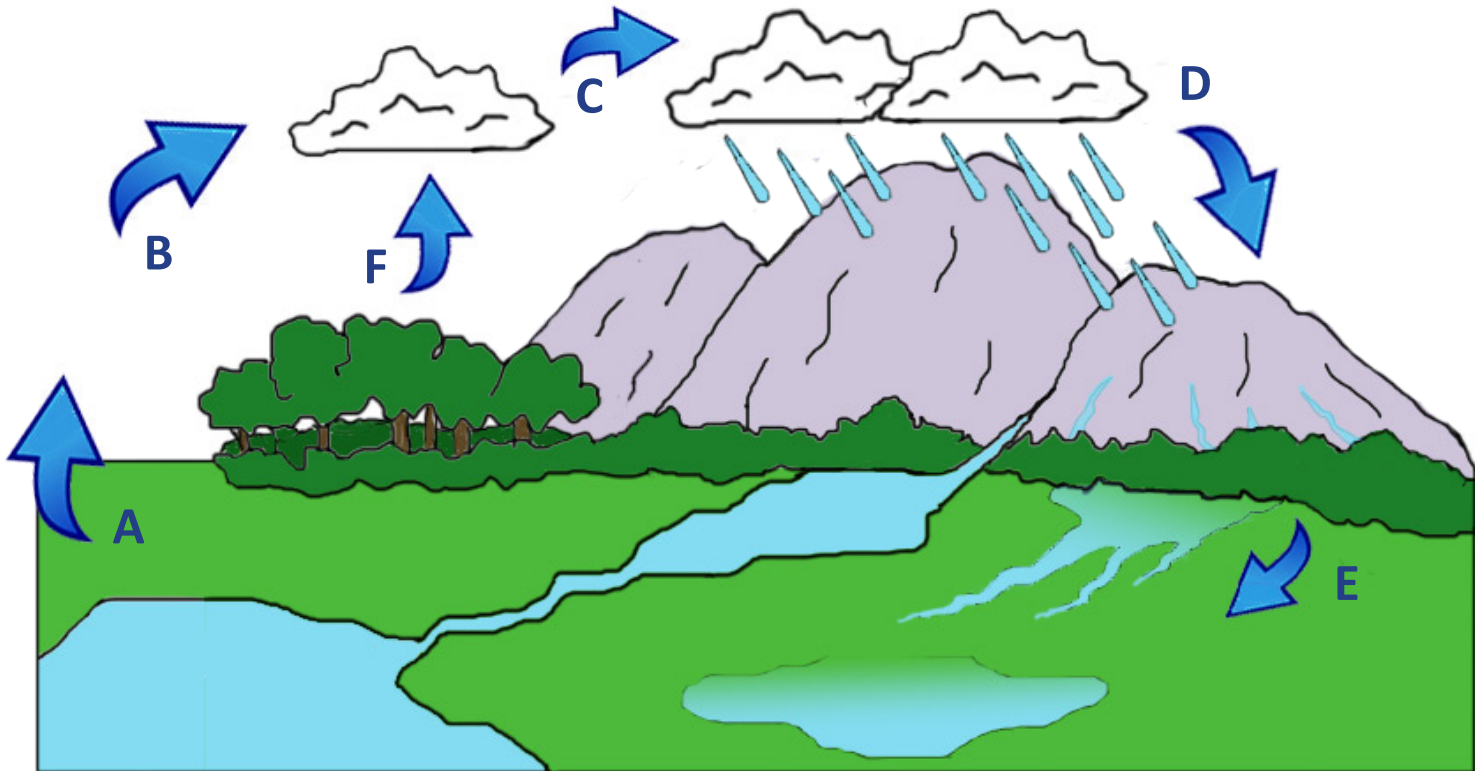
Transpiration

Transpiration is the process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems and flowers

Water Vapor

Gaseous phase of water

Water Cycle Diagram



Use vocabulary to label each step in the water cycle process

A.

B.

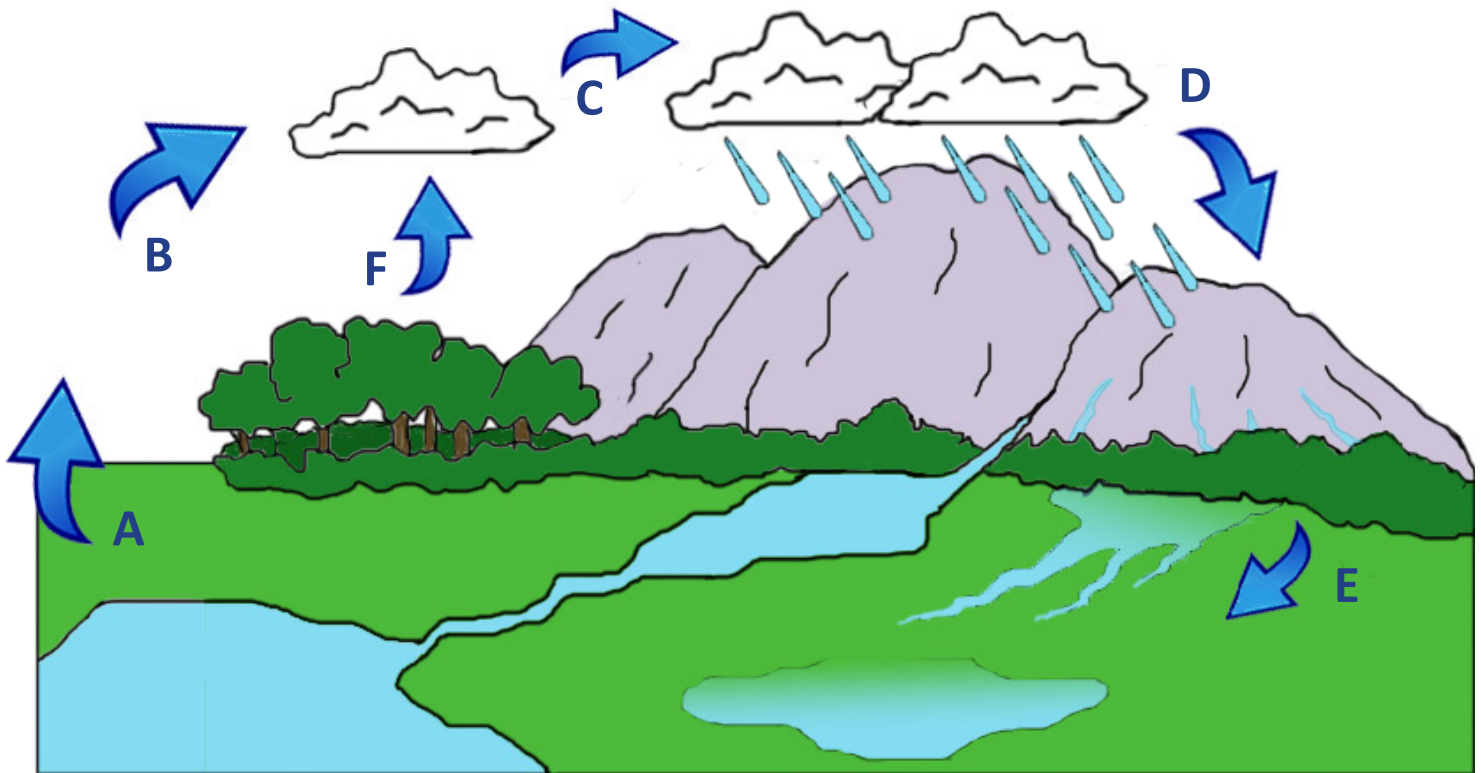
C.

D.

E.

F.

Water Cycle Diagram



Use vocabulary to label each step in the water cycle process

- | | |
|-----------|---------------|
| A. | Evaporation |
| B. | Water Vapor |
| C. | Condensation |
| D. | Precipitation |
| E. | Groundwater |
| F. | Transpiration |

Stormwater Management

Infiltration Experiment

Amount Needed

1
1
1

6
6
12
6
6
6
6
6
6
1

1-2
Multiple
6+
3

2
1
6+

Materials Needed (for 6 groups)

SOILS

Bag of Sand
Bag of Loam (top soil or garden soil)
Bag of Clay

BUILDING & TESTING TOOLS & MATERIALS

Hot glue guns
Metal paint roller trays
plastic paint roller tray liners
500 or 1000 ml beakers
Watering cans
Rolls of Tape
Watering cans
Scissors
Drill

PARKING LOT & DRAIN PIPE MATERIALS

Rolls of aluminum foil (or 1 per group if available)
Cardboard
Straws
Pieces steel wool

OPTIONAL VEGETATION & STRUCTURE MATERIALS

Large sponges
Roll of copper wire cut into 12" pieces
Milk cartons or impervious objects

PROCEDURE

Teacher Preparation

It may be easier to complete the following prior to the students conducting experiments in class.

- Use a power drill to drill three holes evenly across the bottom of the metal paint trays and plastic liners.
- Unroll steel wool and cut width wise into pieces that are approximately 1 inch by 5 inches (need 3 per group)
- For Optional Trees: Cut large sponges into 6 pieces each and cut copper wire into 12 inch pieces

General Guidelines

This experiment should be executed with the Hydrology lesson plan. Review the instructions as a class before conducting the experiment.

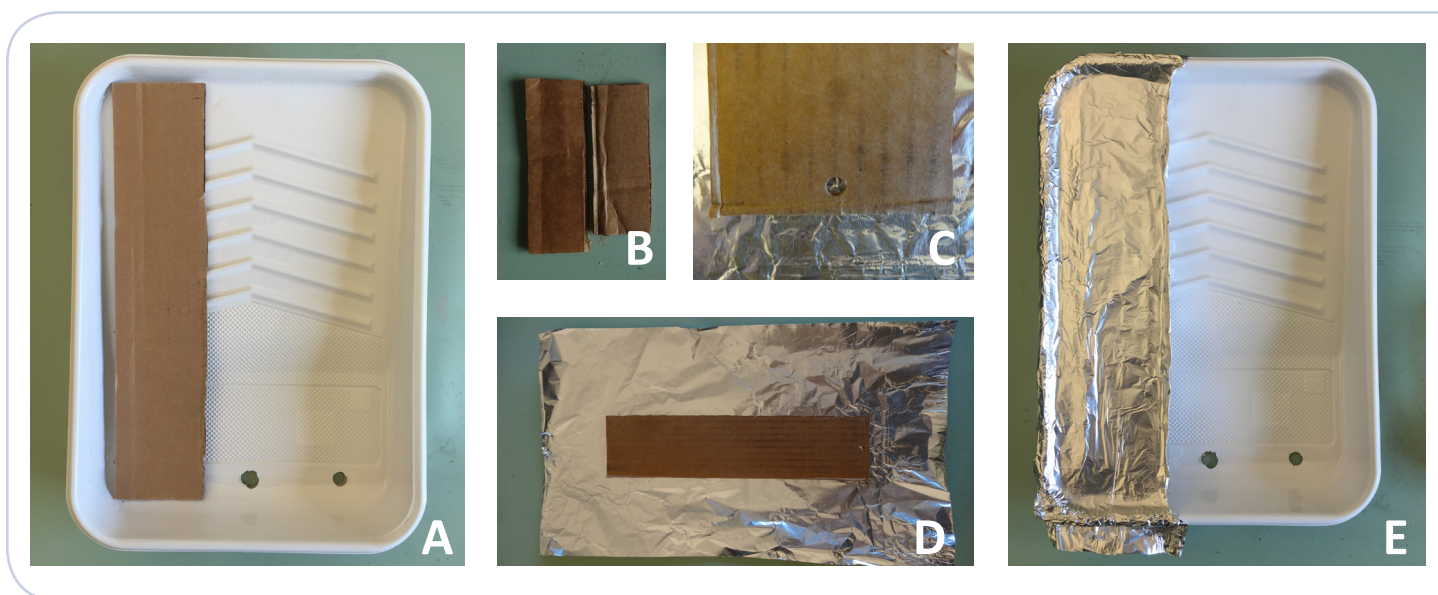
PROCEDURE CONTINUED

Step 1

Prep Cardboard

Cut cardboard into one 3" x 14" rectangle (if cardboard is not large enough to create this size, it can be taped together to reach the correct size). The cardboard should fit inside of the tray and take up approximately one third of the space (see Image A). Use a hole punch to put a hole in the middle end of the 3" x 14" cardboard piece (see image C).

Cut the rest of the cardboard into 1" by 3" rectangles (see image B)



Step 2

Build the impervious parking lot and drain pipe

Place the large cardboard rectangle in the middle of a sheet of aluminum foil that is approximately 12" by 20" (See image D).

Fold the aluminum foil in thirds around the cardboard. Make sure there is at least 1/2 -1" of aluminum foil extended beyond each side of the cardboard. Tape the aluminum foil flap together. Use your finger to gently press the aluminum foil against the cardboard edge to find the hole you previously punched. Use a straw or a pencil to poke a hole through the aluminum foil and hole.

Place the aluminum foil and cardboard piece on the left edge of the paint liner with the hole on the same side as the hole in the paint tray. Use the excess aluminum foil to hold it in place along the edge of the paint liner as well as to create a curb to keep water on the parking lot. (see image E).

Remove the parking lot from the tray and set aside for later.

PROCEDURE CONTINUED

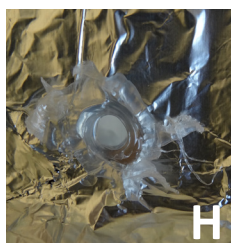
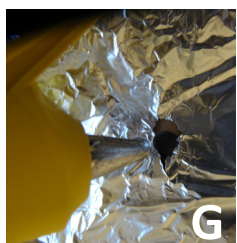
Step 3

Prepare tray and fill with soil

Place the tray liner into the paint tray lining up the drilled holes. Plug up the right hole with steel wool so the soil will not pass through but the water will. Pull the steel wool through the hole so that it sticks out about a half inch from the bottom of the tray and sticks up above the paint liner rim on the top. Repeat for the middle hole. (see image I).

Wrap the third piece of steel wool around the straw. Push the straw and steel wool through the right holes in the tray and liner. (See image I).

Fill the liner with soil up to the rim. Make sure the straw and the two steel wool pieces are sticking up above the soil (See image F and J). Clear debris from the straw before performing the test.



Step 4

Connect pipe to parking lot

Put the parking lot back in place. Stick the straw through the parking lot hole to act as a drain pipe. Holding it flush with the surface of the parking lot, use hot glue to seal the edges of the hole with the straw (See image G and J). Be sure not to remove the straw from the hole.

Once the straw is connected, the impervious pavement variable with curbs and drain pipe is ready to test (See image J).

Skip to step 8 to test the impervious pavement model first.

PROCEDURE CONTINUED

Step 5

Build the permeable pavement LID design

Individually wrap the 1" by 3" rectangles of cardboard in aluminum foil so that they are completely covered. (see image K) Use tape to seal the seams. These pieces will act like permeable pavement.



K



L



M

Step 6

Prepare tray steel wool and fill with soil

Place the tray liner into the paint tray lining up the drilled holes. Plug up all of the holes with steel wool so the soil will not pass through but the water will. Pull the steel wool through the holes so that it sticks out about a half inch from the bottom of the tray and sticks up above the paint liner rim on the top.

Fill the liner with soil up to the rim. Make sure the steel wool pieces are sticking up above the soil (See image L).

Step 7

Place permeable pavement design into tray

Arrange the aluminum foil covered pieces onto the soil along the left edge of the liner. It is ok if the aluminum covers the steel wool. (See image M).

Once completed, the model is ready to be tested.

PROCEDURE CONTINUED

Step 8

Test the models

Fill the watering can with 1 Liter of water.

Place a container underneath all three of the drainage holes (see image N).

Use the watering can to evenly pour the water over the entire tray. Be sure to pour an even amount across all parts of the tray and a consistent rate.

Once the steel wool spouts have stopped releasing water, use the beakers to measure the amount of water collected. Record the amount collected for each model.



Hydrology Questions

Fill out answers in the space below the questions

Question 1

Draw a diagram that shows the differences between the two models you built. Label the different pieces included in each model.

Question 2

What data and results did you collect from your experiment? How did your results differ from that of other groups?

Question 3

What conclusions can you draw from the results you collected? How might your analysis differ from other groups?

Question 4

Were your results different than your hypothesis? If you did not receive the results you expected what do you think affected the experiment?

Appendices

- A. Maryland Environmental Literacy
- B. NEXT-GEN Standards

Appendix A

MD Environmental Literacy

STANDARD 1 ENVIRONMENTAL ISSUES

The student will investigate and analyze environmental issues ranging from local to global perspectives and develop and implement a local action project that protects, sustains, or enhances the natural environment.

Topic A: Environmental Issue Investigation

Indicator 1: Identify an environmental issue.

Indicator 2: Develop and write research questions related to an environmental issue.

Indicator 3: Given a specific issue, communicate the issue, the stakeholders involved and the stakeholders' beliefs and values.

Indicator 4: Design and conduct the research.

Indicator 5: Use data and references to interpret findings to form conclusions.

Topic B. Action Component

Indicator 1: Use recommendation(s) to develop and implement an environmental action plan.

Indicator 2: Communicate, evaluate and justify personal views on environmental issue and alternate ways to address them.

Indicator 3: Analyze the effectiveness of the action plan in terms of achieving the desired outcomes.

STANDARD 2 INTERACTIONS OF EARTH'S SYSTEMS

The student will analyze and apply the properties of systems thinking and modeling to the study of Earth's systems.

Topic A: Earth Systems

Indicator 1: The student will analyze and explain the interactions of earth's systems.

Topic B: Systems Thinking

Indicator 1: Analyze, explain and apply the properties of systems thinking to earth systems interactions.

Indicator 2: Use models and computer simulations to extend his/her understanding of scientific concepts.

STANDARD 3 FLOW OF MATTER AND ENERGY

The student will analyze and explain the movement of matter and energy through interactions of earth's systems (biosphere, geosphere, hydrosphere, atmosphere, and cryosphere) and the influence of this movement on weather patterns, climatic zones, and the distribution of life.

Topic A: Conservation of Matter within Earth Systems

Indicator 1: Demonstrate that matter cycles through and between living systems and the physical environment, constantly being recombined in different ways.

**STANDARD 4
POPULATIONS,
COMMUNITIES
AND ECOSYSTEMS**

Topic B: Energy Distribution through Earth Systems

Indicator 1: Analyze how the position and movement of the Earth in space determine distribution of heat and light.

Indicator 2: Explain that transfer of thermal energy between the atmosphere and the land or oceans produces temperature and density gradients in the atmosphere and the oceans.

Indicator 3: Explain that transfer of thermal energy between the atmosphere and the land or oceans influences climate patterns.

Topic C: Interaction of Physical Systems and the Biosphere

Indicator 1: Analyze and explain the movement of matter and energy through earth's systems and the influence of this movement on the distribution of life.

The student will use physical, chemical, biological, and ecological concepts to analyze and explain the interdependence of humans and organisms in populations, communities and ecosystems.

Topic A: Cycling of Matter and Energy

Indicator 1: Explain how organisms are linked by the transfer and transformation of matter and energy at the ecosystem level.

Topic B: Population Dynamics

Indicator 1: Analyze the growth or decline of populations and identify a variety of responsible factors.

Topic C: Community and Ecosystem Dynamics

Indicator 1: Explain how the interrelationships and interdependencies of organisms and populations contribute to the dynamics of communities and ecosystems.

Topic D: Stability in Populations, Communities and Ecosystems

Indicator 1: Use models and provide examples to show how the interaction and interdependence of populations contribute to the stability of populations, communities and ecosystems.

Indicator 2: Use models and provide examples to show how species' interactions may generate ecosystems that are stable for hundreds or thousands of years.

Topic E: Diversity

Indicator 1: Provide examples and evidence to show that a greater diversity of genes, species and/or environments increases the chance that at least some living things will survive in the face of large changes in the environment.

Appendix A

MD Environmental Literacy

STANDARD 5 HUMANS AND NATURAL RESOURCES

The student will use concepts from chemistry, physics, biology, and ecology to analyze and interpret both positive and negative impacts of human activities on earth's natural systems and resources.

Topic A: Human Impact on Natural Processes

Indicator 1: Analyze the effects of human activities on earth's natural processes.

Indicator 2: Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes.

Topic B: Human Impact on Natural Resources

Indicator 1: Analyze, from local to global levels, the relationship between human activities and the earth's resources.

STANDARD 6 ENVIRONMENT AND HEALTH

The student will use concepts from science, social studies and health to analyze and interpret both positive and negative impacts of natural events and human activities on human health.

Topic A: Natural Changes and Human Health

Indicator 1: Identify and describe natural changes in the environment that may affect the health of human populations and individuals.

Topic B: Human-Induced Changes and Human Health

Indicator 1: Describe and explain that many changes in the environment designed by humans bring benefits to society as well as cause risks.

Topic C: Hazards and Risk Analysis

Indicator 1: Analyze and explain that human activities, products, processes, technologies and inventions can involve some level of risk to human health.

STANDARD 7 ENVIRONMENT & SOCIETY

The student will analyze how the interactions of heredity, experience, learning and culture influence social decisions and social change.

Topic A: Environmental Quality

Indicator 1: Investigate factors that influence environmental quality.

Topic B: Individual and Group Actions and the Environment

Indicator 1: Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests through:

Topic C: Cultural Perspectives and the Environment

Indicator 1: Investigate cultural perspectives and dynamics and apply their understanding in context to:

Topic D: Political Systems and the Environment

Indicator 1: Understand how different political systems account for, manage, and affect natural resources and environmental quality.

**STANDARD 8
SUSTAINABILITY****Topic E: Economics and Environment**

Indicator 1: Analyze and explain global economic and environmental connections.

Topic F: Technology and Environment

Indicator 1: Investigate and examine the social and environmental impacts of various technologies and technological systems on the environment including how:

Indicator 2: Investigate a decision involving the implementation of a new technology and present an assessment of risks, costs and benefits, identification of those who suffer, those who pay, those who gain, what the risks are, and who bears them.

The student will make decisions that demonstrate understanding of natural communities and the ecological, economic, political, and social systems of human communities, and examine how their personal and collective actions affect the sustainability of these interrelated systems.

Topic A: Intergenerational Responsibility

Indicator 1: Understand and apply the basic concept of sustainability to natural and human communities.

Topic B: Interconnectedness of Systems

Indicator 1: Recognize the concept of sustainability as a dynamic condition characterized by the interdependency among ecological, economic, and social systems and how these interconnected systems affect individual and societal well-being.

Topic C: Influence of Economic Systems on Sustainability

Indicator 1: Investigate and make decisions that demonstrate understanding of how the dynamics of economic systems affect the sustainability of ecological and social systems.

Topic D: Influence of Social and Cultural Systems on Sustainability

Indicator 1: Investigate and make decisions that demonstrate understanding of how the dynamics of social and cultural systems affect the sustainability of ecological and economic systems.

Topic E: Limits of Ecological Systems

Indicator 1: Investigate and make decisions that demonstrate understanding of how the dynamics of ecological systems affect the sustainability of social, cultural systems and economic systems.

Topic F: Action Component

Indicator 1: Apply knowledge and skills to investigate and implement personal and collective decisions and actions on an individual, local community, national, and global levels in order to achieve sustainability.

Appendix B

NEXT-GEN Standards

The following standards have been chosen as applicable to the lesson plans in this manual. For more Next-Gen standards visit: www.nextgenscience.org

CODE	DESCRIPTION
3-ESS3-1.	Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
3-5-ETS1-2.	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3.	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
4-ESS2-1.	Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
4-ESS2-2.	Analyze and interpret data from maps to describe patterns of Earth's features.
4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1.	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
MS-ESS3-3.	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS2-4.	Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
MS-ETS1-1.	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2.	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Appendix B

NEXT-GEN Standards

CODE	DESCRIPTION
MS-ETS1-3.	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4.	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
HS-ESS3-3.	Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
HS-ESS3-4.	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ESS3-6.	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
HS-ETS1-2.	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3.	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.



Landscape Architecture

DEPARTMENT OF PLANT SCIENCE AND LANDSCAPE ARCHITECTURE