WATERWISE GARDEN STEWARDS LESSON GUIDE

Water is an essential component of all living things, including plants. Middle school student gardeners are at a stage in their learning where they're ready to look closely at water's importance in our ecosystems and how our actions in gardens and landscapes can impact its availability and quality on local, regional, and global scales. In this unit of Waterwise Garden Stewards, students will use gardens for investigations exploring water on micro and macro levels. They will discover how their actions can help conserve and preserve our water resources.

This unit includes five modules:

- Water in Plants
- The Water Cycle
- Water in a Changing Climate
- Waterwise Landscape Design and Management
- Irrigation Design

Each module includes three water-focused, garden-related experiments or activities with background information so students can engage in hands-on experiences to deepen their understanding of water. Students will also learn about best practices for watering the garden as well as basic irrigation design. The target age for content and activities is sixth through eighth grade.

Waterwise Garden Stewards
Module 1: Water in Plants

Learning Objectives

Water is critical for healthy plant growth and development. This module focuses on how water is integral to fundamental plant systems and why it is so important for gardening. Students will:

- Explore traits of water that help it support basic plant functions.
- Investigate how water moves through plants.
- Observe how water impacts plant growth and development.

Activity 1: Water Molecules

Learning Objective:

Students will explore traits of water that help it support basic plant functions.

Background Information:

Consisting of one oxygen atom bonded to two hydrogen atoms, a water molecule is seemingly simple, yet it is essential for all life on Earth. With over 71% of Earth's surface covered with water, it is found in large quantities on the planet. However, only about 1% of this water is in a form that can be used by land plants and animals. (96.5% is salt water and the rest is frozen or inaccessible ground water). Water is one of the few substances we naturally see in each of it states (solid, liquid and gas) on a regular basis. Constantly changing through these states, water moves from land (found on the surface and underground), to air through evaporation, and eventually returning to land through precipitation. Collectively, this movement is known as the Water Cycle.

Plants fulfill the bulk of their water needs by taking it up from the soil through their roots (though some plants can capture small amounts of water through their leaves). Plants use water to perform vital functions, including helping with the transformation of energy through photosynthesis, aiding in nutrient transport, providing support for cell and plant structure, and helping with cooling. Without adequate water supplies, plant development will be stunted, and growth will slow or cease altogether.

Properties of Water
To understand how water moves through and is used by plants, it helps to understand some of its basic properties.

Cohesion and Adhesion – Water is sticky. It likes to join with other molecules, including fellow water molecules (cohesion), and also other substances (adhesion). The atoms that make up a water molecule are arranged so that the molecule has a slight positive charge on one side and a slight negative charge on the other. The positive side of a water molecule attracts the negative side of a nearby water molecule (similar to the way the north pole of a magnet attracts the south pole of another magnet), causing them to "stick" together (cohesion). Similarly, these slight charges cause water to tend to adhere to other substances (adhesion). Learn more.

Surface Tension – Since water likes to stick to itself, the top layer of water will bond more strongly to lower layers, since they have fewer water molecules to bond to. Surface tension is the reason water forms droplets, and it aids in the ability of plants to take up water. Learn more.

Capillary Action – Capillary action is the movement of water against gravity due to the combined properties of adhesion, cohesion, and surface tension. Capillary action is important to plants because it helps move water up from the roots and into the stems. Learn more.

Universal Solvent – Water is known as the universal solvent because of its ability to dissolve a great number of substances. This quality is important for plants because water helps dissolve nutrients in the soil and, through mass flow, helps get those nutrients to the roots' surfaces for absorption. Learn more.

Specific Heat Capacity – Water has a high specific heat capacity, meaning it can absorb a lot of heat energy before its temperature rises significantly. Thus, water helps regulate environmental extremes. Plant foliage has a high water content. Because of this, plants can absorb heat and then release it through evaporation during the process of transpiration. Just like sweat helps animals prevent overheating, water vapor released by plants helps keep plants cool. Learn more.

Resources:
Water Science School. U.S Geological Survey. https://www.usgs.gov/special-topics/water-science-school

Materials:

- Dry erase board and markers
- Molecule model kit or craft supplies
- Clear jar
- Watering can
- Paper towels
- Food coloring
- Bucket of water
- Assorted natural materials
- Liquid or solid soluble fertilizer

Instructions:

1. Begin the lesson by asking students to brainstorm a list of everything they know about water, either as a class, in small groups, or individually. Have students share their lists and sort findings into categories. Examples of possible categories may include physical characteristics, uses, and sensory observations.

2. Make a model of a water molecule using a molecule building kit or craft supplies. Introduce some of the traits of the water molecule that are relevant to how plants use water using the background information. The video [Molecule Profile: H20 – Water](https://www.youtube.com/watch?v=b-_DJaQivdU) at https://www.youtube.com/watch?v=b-_DJaQivdU from NBC News Learn provides a helpful overview for support.

3. Pair the information about traits of water with a few hands-on activities in the garden to help students apply the information in a real-world setting. Here are some possible activities:
    - Change of States: Fill a clear jar with an inch or so of water and seal with a lid. Turn the jar over and place it in a warm, sunny location in your garden. Let it sit in the sun for a few hours and return for observations. Water should evaporate and water droplets condense against the jar as temperatures inside the jar will be higher than those outside. Discuss why and how water moves from liquid to gas state and what that means for your garden plants.

    - Adhesion: If season permits, visit the garden early in the morning when dew can be found on leaves. Lift horizontal leaves into a vertical position and watch how the water drops tend to join together as they slide down the leaf and roll off to the ground in one plop. If timing or season are not a good fit, you can apply water to leaves to prepare for observation. (Make sure to remind students that, when watering plants, it is best practice to apply water directly to the soil.)

    - Cohesion: After watering the garden, have students look inside the watering can to see if any water remains. Challenge them to see if they can get all the water out of the can. Discuss why the water sticks to the can.

    - Capillary Action: For a quick demonstration, add a couple of drops of food coloring to a glass of water and insert the end of a paper towel. Watch the water move up the towel against gravity. For a longer demonstration, try the classic "celery in a jar" experiment.

    - Surface Tension: Fill a bucket with water. Let students experiment with finding objects in the garden (leaves, seeds, fruit, sticks, etc.) and first predict and then test to see whether they sink or float. At the end of the experimenting, discuss surface tension and how it enables even objects with a higher density than water float on its surface.

    - Universal Solvent: Add solid or liquid fertilizer to a clear bottle and discuss how dissolving nutrients in water helps make the nutrients available to plant roots.

Activity 2: Water Movement

Learning Objective:

Students will investigate how water moves through plants.

Background Information:

Most water used by plants originates in the soil. There are some plants adapted to take in water through their leaves, but the vast majority obtain water through roots (or, more specifically, through root hairs). The plant then moves the water up the stems through specialized xylem cells (similar how the circulatory system works in animals). It is then delivered to the leaves where it is used in plant cells. Additionally, some of the water exits the leaves through small openings called stomata through a process known as transpiration (similar to the process of sweating in humans).

Important to note is that in plants, water is moving against the force of gravity. This feat is accomplished through a combination of factors. Water moves into the roots through osmosis and is pushed upward into the stem though capillary action. Not only do water molecules cohere to one another, forcing the water column further upward, they also adhere to the sides of the conducting tissue. In addition, transpiration, which is the evaporation of water through leaf openings, pulls the water column upward. Therefore, water is being pushed and pulled up through the plant at the same time. In some plants and in some conditions, water can move through stems as fast as 30" per minute.

The influx of water keeps plant tissues filled with water (turgid) so that they can provide structural support for the plant. (Plant tissues that lack water lose turgidity and may wilt.) It also helps plants adapt to varying conditions in their environment. The availability of water is key to a plant's ability to perform photosynthesis, which is how the plant converts light energy into food.

Resources:

Lessons to Grow By – Plant Needs, Water. KidsGardening. https://kidsgardening.org/product/lessons-to-grow-by-plant-parts/

Materials Needed:

- Woody shrub or tree
- Plastic sandwich or quart-sized bags
- Tape, twist tie or rubber bands
- Water Experiment Observation Worksheet
- Radish seeds (optional)

Instructions:

1. Identify a small tree or large woody shrub you can use for observation. Choose a plant you can visit at least twice a day.

2. Each morning for one or two weeks, place one or more dry plastic bags over the end of a stem(s), making sure to include 3 or 4 leaves in each bag. Carefully seal the bag with a twist tie, rubber band, or string so that it is snug around the stem(s), being careful not to damage the plant.

3. Each afternoon, return to your plant and observe what you find. (Hint: You should find varying amounts of water vapor inside the bag.) Record findings on the Water Experiment Observation Worksheet. Remove the plastic bag and replace with a dry one (towel off any water drops on leaves if needed). Observe the new bag(s) the next morning.

4. Repeat over multiple days by placing new dry bags on the same leaves each morning and switching it out at night (you can re-use bags, but just make sure they are completely dry when first attached). For best results, you should observe over a mix of sunny and cloudy days (or if your plant is in a container you can move the plant to sunny or shady locations).

5. At the end of experiment, compile your results and discuss your findings. Ask students to consider:
   - Where did the moisture in the bags come from? Did the amount present vary depending on the environmental conditions? Did you note any difference between morning and afternoon observation times? Did the amount vary over the length of time we conducted the experiment? What do you think this means for the leaves we did not cover?
   - Did this experiment help support the concept that water moves through plants from roots to leaves? Why or why not?
   - What did you learn from this experiment? If you conducted this experiment again, what would you do differently?

Extend the Learning:

Below Ground: Root hairs are responsible for much of the water absorption of roots. Newly germinated radish seeds provide the opportunity to see and explore root hairs. Place a few radish seeds in a plastic bag with a moist paper towel and let students observe roots as they grow.

Above Ground: Students can see plant stomata in action through this short video clip from SciTech Daily: https://www.youtube.com/watch?v=QEF5KgaDdfs.

Water Experiment Observation

Date	Time (circle one)	High and Low Temperature for the Day	Sun Exposure (circle one)	Bag Moisture (circle one)	Notes
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	
	AM PM		Sunny Partly Cloudy Cloudy	Light Moderate Heavy	

Activity 3: Water Needs

Learning Objective:

Students will observe how water impacts plant growth and development.

Background Information:

Since water is necessary for photosynthesis, it is also essential for healthy plant growth. Through photosynthesis, a plant converts the sun's energy into its food source. Without adequate food production, a plant will not grow to its full potential. Signs a plant is not having its water needs met include:

Stunted growth – Water stress will decrease photosynthesis and the plant's ability to make new plant cells. The younger the plant is, the bigger the impact. Seeds will not germinate and seedlings will stop growth without adequate water availability.

Wilting or drooping leaves and bending stems – One of the first signs of stress, wilting indicates that the water supply is inadequate, which impacts the plant's ability to support itself.

Browning or crispy leaf edges– Water helps protect the plant from extreme temperatures. If water is limited, areas of the leaf farthest from leaf veins will be impacted first.

Yellowing leaves and leaf drop – Plants under severe water stress may be triggered to enter into a dormant period. They will drop leaves to decrease their water needs.

Too much water can also impact plant growth and development. Underground, plant roots need both moisture and air for proper functioning. When soil is saturated, there are few air pockets to provide that balance of water and air. This can lead to root damage and death, which can in turn lead to wilting and yellowing of foliage. In addition, too much water in the soil and water that remains on leaves too long can lead to disease problems caused by the growth of harmful bacteria and fungi. The symptoms of not enough water are very similar to those of too much water, making diagnosis a challenge. This makes the tracking of soil moisture so important.

How much water do plants need? There is no easy answer to that question. The amount of water a plant needs varies on environmental conditions, including temperature and sun exposure and very from day to day and season to season. Plants in hot, dry conditions will lose water more quickly than plants in cool, humid conditions. In the summer, water needs are high. During the winter, some plants drop their leaves and enter a dormant state where they use very little, if any, water.

The amount of water needed will also vary depending on the type of plant. Plants are naturally adapted to need the amount of water provided by their native habitat. For example, on one extreme are cacti that live in deserts where water is scarce. They have modified leaves (spines) that decrease the rate of transpiration, and their stems have a special ability to store extra water. At the other extreme are rainforest plants, many of which have pointy tips (drip tips) and waxy surfaces that help excess water slide off quickly. These help prevent water buildup that could lead to decay and mold. Since natural water needs vary, gardeners must research the water needs of their plants and become keen observers to be able to provide what is needed.

Resources:

Amazing Adaptations of Succulents. KidsGardening. https://kidsgardening.org/resources/lesson-plan-amazing-adaptations-succulents/

Tropical Rainforests. KidsGardening. https://kidsgardening.org/resources/lesson-plan-tropical-rainforests/

Lessons to Grow By – Plant Needs, Water. KidsGardening. https://kidsgardening.org/product/lessons-to-grow-by-plant-parts/

Materials:

- Experiment Planning Worksheet
- Materials needed for experiments

Instructions:

1. Review why plants need water including:
    - to perform vital functions including helping with the transformation of energy through photosynthesis
    - to aid in nutrient transport
    - to provide support for cell and plant structure
    - to keep plants cool

2. Ask students some questions to help them dig deeper into a plant's need for water. Do all plants the need the same amount of water? Do they need the same amount of water every day? What kind of factors might determine how much water a plant needs? How do we know if they are getting enough water? How do we know if they are getting too much water? What happens if they do not get the correct amount of water?

3. Challenge students with creating an experiment to investigate how much water plants need and what happens if they get too much or too little. This can be done as a class project, in groups, or individually. They can use the Experiment Planning Worksheet as a guide.

    Provide guidance and suggestions as needed. Explain to them that since the goal is to test the impact of water availability and quantity on plants, they need to limit the number of variables that might impact their results. Therefore, their experiments should focus on only changing the amount of water delivered to plants. Some tips you may want to provide include:

- Use the same size containers
- Grow the same kind of plants
- Try to find plants that are approximately the same size and health at the start of your experiment
- Grow all the plants in the same environmental conditions (same light, temperature, and humidity)

4. Share and evaluate the experiment proposals as a class. Brainstorm ways to improve on the experimental design of each.

5. Depending on time and resources available, implement one or more of the proposed experiments. Collect, analyze, and report on data collected.

6. At the end of the experiment, ask students to list the signs that plant that has received adequate, too much, or not enough water. If your class was not able to conduct their own experiments, have them conduct online research to find examples. Discuss each of the noted signs and why they occur.

Extend the Learning:

Dig deeper into the process of photosynthesis and the role water plays. [Photosynthesis 101](https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/) at https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/ provides additional background information for support. [Photosynthesis Runs the World](https://kidsgardening.org/resources/lesson-plan-photosynthesis/) at https://kidsgardening.org/resources/lesson-plan-photosynthesis/ provides lesson and activity ideas.

Experiment Planning Worksheet

Experiment Brainstorming:

1. What question are we trying to answer through this experiment?

2. What independent variable are we investigating?

3. What is the dependent variable in our investigation?

4. What variables do we need to control in our experiment?

5. What do we already know about this topic?

6. What do we need to learn about this topic?

7. What is our hypothesis?

Experimental Design:

1. Provide an overview of how you plan to test your hypothesis:

2. What supplies are needed:

3. List the specific steps of the investigation:

    1.

    2.

    3.

    4.

    5.

    6.

    7.

4. What kind of data should be recorded?

5. How will you record your data? Create a data collection tool on a separate piece of paper.

6. How will you analyze the data and share your results?

7. Can you think of any limitations your experiment might have?

Module 1 Next Generational Science Standards

The following standards inspired the activities in this Waterwise Garden Stewards module:

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-LS1-1. Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Waterwise Garden Stewards
Module 2: The Water Cycle

Learning Objectives

Water's cycling through the environment is a key phenomenon supporting life on Earth. This module focuses on Earth's water systems with an emphasis on the water cycle and the role of plants, gardens, and landscapes. Students will:

- Discover the role of plants and soil in the water cycle.
- Learn that our gardens and landscapes are part of watersheds and rely on both rainfall and municipal water systems.
- Consider the potential impact of gardens and landscapes on water systems.

Activity 1: The Role of Plants in the Water Cycle

Learning Objective:

Students will discover the role of plants and soil in the water cycle.

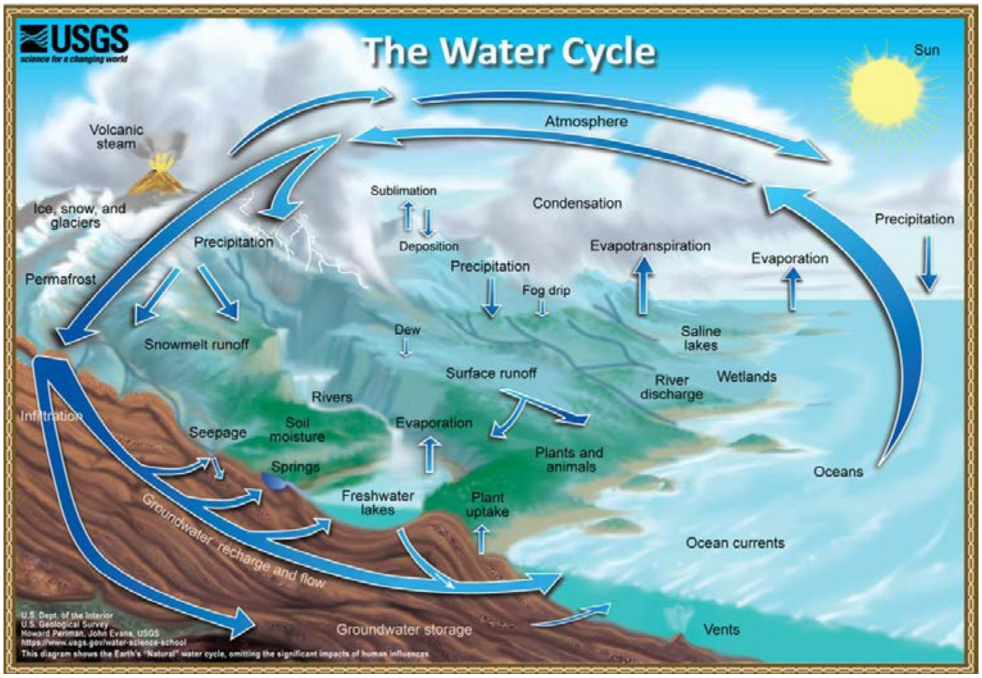
Background Information:

The movement of water through plants is part of a bigger phenomenon known as the water cycle. In the water cycle, water evaporates from surface water sources and through evapotranspiration of plants into the air, where it then condenses into clouds. Then, by way of precipitation (mainly rain and snow), it returns to the earth where it is absorbed into the soil and collects in streams, rivers, lakes, and ultimately oceans to begin they cycle again.

Once it reaches the ground, precipitation can take one of two pathways: surface runoff or infiltration. The infiltration of water into the soil provides many environmental benefits. Healthy soil works like a sponge, soaking up water and allowing it to be processed slowly into the environment while impurities are removed. Plants then provide a second layer of filtering as they selectively take up water and nutrients from the soil and release water vapor in pure form as they transpire.

Plants are important partners in the creation and maintenance of soil with high infiltration capability. First, plant canopies help slow the rain before it hits the ground, softening the force with which it lands which reduces runoff and provides more time for absorption. Plant roots also contribute to healthy soil structure. Plant roots give off exudates that consist of carbohydrates produced by the plant through the process of photosynthesis. These exudates become food for bacteria and fungi in the soil. In turn, microscopic organisms are consumed by slightly larger life forms (although in most cases still too small to see with the naked eye), such as nematodes, protozoa, and some arthropods. These organisms are eaten in turn by larger creatures that can be seen without a microscope, such as larger arthropods (like millipedes and sow bugs) and earthworms. Soil structure is highly influenced by these underground critters. Many of the organisms excrete bodily fluids that act like a glue to help soil particles stick together into clumps called aggregates. Soil organisms also help break down organic matter in the soil. The formation of aggregates and decomposition of organic matter help create pore space that is so vital for the absorption of water.

Plants also help protect water that runs off rather than being absorbed. Roots keep soil in place when exposed to weather such as rain and wind, preventing it from eroding into waterways.



The Water Cycle. Credit: Howard Perlman, John Evans, USGS
https://www.usgs.gov/media/images/natural-water-cycle-jpg

Resources:
The US Geological Survey of the Department of the Interior provides a number of diagrams available at: https://www.usgs.gov/special-topics/water-science-school/science/water-cycle-diagrams to help teach students about the water cycle including:

The Water Cycle: This diagram depicts the water cycle and includes the role of human developments.

The Natural Water Cycle: This diagram depicts what the water cycle would look like without human influences.

The Water Cycle for Kids: This diagram was designed specifically for young learners for an easy introduction to the water cycle.

The Atmosphere and the Water Cycle, Water Science School. USGS. https://www.usgs.gov/special-topics/water-science-school/science/atmosphere-and-water-cycle

Materials:

- USGS water cycle posters
- Red, green, and blue markers
- Materials for a water cycle model (will vary depending on model choice)

Instructions:

1. Study the USGS water cycle posters with your students. Begin with the Natural Water Cycle Diagram. Using a large classroom poster or projection of the graphic or by passing out individual student worksheets, circle all the sources from which water can evaporate from in red. Next, add a second circle to all these sources that are (or contain) plants in green marker. Discuss the role of plants in the water cycle based on this diagram. According to USGS, 10% of water in the atmosphere is from plant transpiration.

2. Next, study the Water Cycle Diagram. Again, circle the sources of evaporating water in red marker followed by those that contain plants in green marker. Then, circle in blue marker all of the water sources that are impacted by humans (many sources will be circled two or three times). Based on this diagram, talk about the ways human activity can affect water at each of these points. Do we impact water in a positive or negative way? Where do our gardens and landscapes fit into the water cycle?

3. To reinforce students understanding of the water cycle, task them to create their own model explaining how water moves through the world. Some possible model ideas include:

   - Build a Terrarium – Use recycled containers or old aquarium to build a miniature ecosystem using rocks, soil, and plants. Directions can be found at https://kidsgardening.org/resources/garden-activities-building-a-terrarium/.
   - Make a Movie - Create a stop motion movie using clay or other art supplies using an app like Stop Motion Studio at https://www.cateater.com/.
   - Write a Play – Student can act out the stages of the water cycle and create illustrative props and settings.
   - Create a Slide Presentation – Students can create a slide presentation about the Life of a Drop of Water.

Activity 2: Watersheds

Learning Objective:

Students will learn that our gardens and landscapes are part of watersheds and rely on both rainfall and municipal water systems.

Background Information:

As precipitation falls, water will either be absorbed into soil or it will flow along the surface by way of gravity to lower elevations and collect in streams, lakes and rivers. A watershed is an area of land defined by having water drain to a central point due to the land's topography. Any water that infiltrates and is stored under that land is also counted as part of that watershed. Defined by the outflow location, larger watersheds based around major rivers are made up of clusters of smaller watersheds situated around smaller rivers, streams and creeks. American's Watershed Initiative offers a graphic of the Mississippi River Watershed that provides a good visual of how smaller watersheds can combine together into one. The EPA offers a map of the 22 major watershed regions in the United States for a national scale view. For a local perspective, the EPA offers a handy tool that uses zip codes called How's My Waterway? that can be used to identify the smallest watersheds.

In addition to the natural flow and storage of water in an ecosystem, water is also moved in a community through public water and sewer systems. These systems are created and maintained by local entities, including county, cities or special utility districts, with oversight by states and at the national level by the EPA's Office of Water. Through these systems, municipalities take water from both surface and ground water sources (which are both part of the watershed), treat it to remove impurities, and then pipe potable water to homes and businesses in the community. Wastewater is then collected through sewer systems and is carried to water treatment plants to filter out containments before being returned to surface and ground water sources. Homeowners living outside of city limits may also access water from individual wells and treat wastewater using septic systems.

Water for our gardens and landscapes is drawn both from naturally occurring water from rainfall and runoff and from human controlled water sources by way of municipal water systems and irrigation.

Resources:

Watersheds and Drainage Basins. USGS. https://www.usgs.gov/special-topics/water-science-school/science/watersheds-and-drainage-basins

Watersheds: Role, Importance & Stewardship. Mississippi State University Extension. http://extension.msstate.edu/publications/watersheds-role-importance-stewardship

Mississippi Watershed Map. American's Watershed Initiative. https://americaswatershed.org/americas-watershed/

Watersheds. EPA. https://www.epa.gov/trinationalanalysis/watersheds

How's My Waterway. EPA. https://mywaterway.epa.gov/

Materials Needed:

- Plastic bin
- Assorted cups in different sizes
- Tin foil
- Water spray bottle
- Cocoa powder
- Where Does Our Water Come From? Worksheet

Instructions:

1. Introduce students to watersheds. If they have trouble conceptualizing the concept of a watershed, try this DIY Watershed Activity shared by the San Antonio River Authority at https://www.youtube.com/watch?v=lYLDMmivygk. In this activity, cups of different sizes are placed in a plastic bin and then covered with tin foil creating different sized valleys. Using a water spray bottle, simulate rain so students can watch how it moves and collects in the model landscape.

2. Ask students to think about your school garden or landscape and/or their home garden or landscape. How do our garden/landscape plants get water? Where does the water come from? Where does any extra water go? If possible, visit your space during or immediately after a rain and look for runoff and water absorption.

3. Use the Background Information to inform students that some of our water comes from water's natural pathways and some is provided by municipal water sources moved by humans. Some of the water is absorbed into the soil, while other water flows over the surface into local creeks, streams and rivers.

4. As a class or in groups, use the Where Does Our Water Come From? worksheet to explore both natural and man-made water resources in your community. Begin by using the How's My Waterway? tool to identify your local watershed. Next, expand to see how your watershed fits into the water systems in your county, state and then the country.

5. After researching natural water movement, explore how water arrives at your faucets. You can search by obtaining a water bill for your location to identify the entity charging you for your drinking water. You can also use the EPA's Drinking Water Mapping Application to Protect Source Waters (DWMAPS).

Extend the Learning:

Invite a Guest Speaker: Invite a local water expert or employee from your local municipal water service to share more about your local water system.

Research Wastewater Treatment: The handling and release of wastewater is another important component of local water systems. The EPA also has some excellent Municipal Wastewater resources including the Simplified Urban Water Cycle info graphic on page 7 of the Primer for Municipal Wastewater Treatment Systems.

Where Does Our Water Come From?

Using the How's My Waterway? tool at: https://mywaterway.epa.gov/, find your watershed and complete the following:

1. Watershed Name:
2. Watershed Size:
3. List the major waterways found inside your watershed and note their condition rating (good, impaired or condition unknown):
4. Are there any water monitoring locations?

Draw a picture of your watershed:

Using a water bill or the EPA's Drinking Water Mapping Application to Protect Source Waters (DWMAPS) at https://geopub.epa.gov/DWWidgetApp/ find your local water provider:

1. Who operates your water provider?
2. What is the primary source of your water?
3. How many people are served by your municipal water system?

Activity 3: Water Systems

Learning Objective:

Students will consider the potential impact of gardens and landscapes on water systems.

Background Information:

Human actions (including activity in gardens and landscapes) can impact water systems in a number of ways. USGS shares this list of common ways humans can alter the water cycle.

- Alter natural water storage and movement. Dams are used to change rivers' pathways, make lakes and generate electricity. Ground and surface water sources are tapped for municipal water delivery and to dispose of treated wastewater.

- Disrupt natural watersheds by grading land. Development can lead to the draining of wetlands and altering topography which makes permanent changes to natural water pathways of watersheds.

- Contaminate water with pollutants. Although some pollutants like litter are obvious to the naked eye, soluble contaminants can be even more harmful. From the perspective of garden, landscape and agricultural lands, fertilizers and pesticides that are applied to help plants grow can be picked up by water runoff and potentially harm wildlife downstream.

- Cause soil erosion. When existing vegetation is removed, soil impacted by water and wind can be picked up by runoff water and clog waterways.

Recognizing the impact and identifying specific sources of contamination humans can have on our water systems are the first steps to changing our attitudes towards water resources and finding ways to conserve and protect them.

Resources:
The Water Cycle. Water Science School: https://www.usgs.gov/special-topics/water-science-school/science/water-cycle

Materials:

- Three or more old 9" x 13" baking pans or disposable aluminum pans
- Potting soil or soil from a garden
- Fast-growing seeds such as grass
- Plastic trays
- Watering can

- Water
- Food coloring
- Pop Rocks Candy
- Garden Runoff Experiment Worksheet

Instructions:

1. The watering we apply to our gardens and landscapes eventually ends up in our water sources via one of two paths. It can be absorbed by the soil and make its way into ground water, or it can run off into local waterways. Students will conduct an experiment to simulate how soluble chemicals applied to plants can end up in our water sources.

2. Fill three or more old 9" x 13" baking pans (or disposable aluminum pans) with potting soil or soil from the garden. Plant fast-growing seeds (grass seed works well) and then let them grow for few weeks until they've become established. Allow plants to grow until you can give them a gentle tug and feel that they're firmly rooted.

3. Set the pans on a table at a slight angle (10° to 20°) with the bottom end placed in a waterproof tray. Use a watering can with a sprinkler head (rose) to simulate rain on three "pan landscapes." As you water each one, try to expose each pan to the same amount of water at the same rate of delivery.

    - Pan 1: Before watering, sprinkle some Pop Rocks candy over the plants to represent granular fertilizers and pesticides.

    - Pan 2: Add food coloring to the water before the "rain" to represents liquid fertilizers and pesticides.

    - Pan 3: Water with plain water.

    Track and apply the water until it's flowing out of the pans.

4. Compare the quality of water runoff from each landscape and record it using the Garden Runoff Experiment Worksheet. Are there any differences? What does this teach us about using chemicals in our gardens? Do our garden plants need fertilizer and pesticides? What should we do with this information? Are there any alternatives we could use?

Before

After

Garden Runoff Experiment Worksheet

Treatment: Panscapes received different additives to represent different forms of fertilizers/pesticides.

Pan #	Treatment	Describe the color of the runoff water:	Additional observations:
Pan 1:	Water only		
Pan 2:	Pop Rock Candy (representing granular fertilizer)		
Pan 3:	Food coloring added to water (representing liquid fertilizer)		

1. Based on this experiment, can garden additives enter our ground and surface water?

2. Why is that important to know?

3. How should this information impact our gardening practices?

Module 2 Next Generational Science Standards

The following standards inspired the activities in this Waterwise Garden Stewards module:

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

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-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Waterwise Garden Stewards
Module 3: Water in a Changing Climate

Learning Objectives

Climate change is leading to a rise in concerns about water supplies around the globe. This module will focus on introducing students to some of the challenges facing our water systems today. Students will:

- Investigate how ground water and surface water supplies are used by people.
- Learn about changes in water availability on a local and national scale.
- Explore how much water is used in gardens and landscapes.

Activity 1: Water Supplies

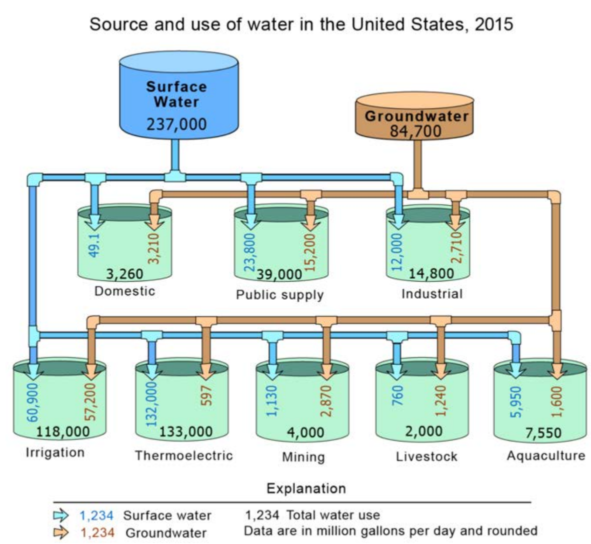
Learning Objective:

Students will investigate how ground water and surface water supplies are used by people.

Background Information:

As human populations grow and their use of natural resources expands, water systems are significantly impacted. Some of the top threats to clean water supplies include:

- Increased pollution.
- Demand that exceeds supply.
- Extreme weather events, such as floods and droughts, due increasing atmospheric greenhouses gases triggering climate change.



Based on data compiled in 2015, the USGS put together a visual tool to explain how and how much water is used daily in the United States from both surface and ground water supplies. They divided water use into eight major categories: domestic, public supply, industrial, irrigation, thermoelectric, mining, livestock and aquaculture. They report that an estimated 322 billion gallons of water are used daily in the United States, with the top 3 uses being thermoelectric power (41% of total withdrawals), irrigation (37% of total withdrawals) and public supply (12% of total withdrawals). For more details, check out the full report by USGS for Estimated Use of Water in the United States in 2015 or the more concise summary. A more generalized infographic of Water Use in the U.S. is also available.

To complement learning about water use on a national scale, students benefit from exploring water use on a local level. The organization EcoRise has developed a Water Footprint® Calculator that can be used to investigate how much water an individual or household uses by answering a series of survey questions. Not only does the survey provide a water use estimate, the survey questions can also help students expand their understanding of the important role of water in daily life.

Resources:

Source and Use of Water in the U.S. in 2015. Water Science School. USGS.
https://www.usgs.gov/media/images/source-and-use-water-us-2015

Estimated Water Use in the United States in 2015. USGS. https://pubs.usgs.gov/publication/cir1441

Summary of Estimated Water Use in the United States in 2015. USGS.
https://pubs.usgs.gov/fs/2018/3035/fs20183035.pdf

Water Use in the U.S. – daily water use. USGS. https://www.usgs.gov/media/images/water-use-us-daily-water-use

Water Footprint Calculator. EcoRise. https://watercalculator.org/

Materials:

- Water Inventory Worksheet

Instructions:

1. Give each student a copy of the Water Inventory Worksheet and ask them to keep track of the water they use in a day. Remind them to think about hidden water use, like consumption of food that requires water inputs to be produced/grown/cooked and electricity they use that may be generated by a hydroelectric plant.

2. After filling out the inventory, share results and create a class water inventory list of daily water use.

3. Next, use the Water Footprint® Calculator from EcoRise to further explore how we commonly use water each day. They can answer the survey individually, in groups or you can complete it together as a class using a hypothetical household as an example.

4. After completing the survey, ask students, Did the questions on the calculator change the way you think about water use? Did any of the questions surprise you? Does it give you any ideas of ways you could save water? After completing the survey, is there anything you think we should add to our class water inventory list?

5. After completing the inventory, divide the class into small groups and ask them to sort your class list into rank order of importance. The top of the list should be water essentials that are needed for survival. The bottom of the list are things we use water for that are optional. At the end of the ranking, each group should share their rankings and reasoning. Discuss differences and similarities between the lists. How could we use our rankings to consider and weigh options for conserving water?

6. At the end of the activity, share the Source and Use of Water in the US info graphic from USGS. Sort the items on your list into each of the categories.

Extend the Learning:

Ask students to research ideas for decreasing water use and compile the findings into a format that can be shared such as a newsletter article, poster or presentation. Resources they can use for this research include:

Water Footprint® Calculator's How To Save Watery: https://watercalculator.org/how-to-save-water/
EPA's Start Saving Resource: https://www.epa.gov/watersense/start-saving

Water Inventory Worksheet

Use the chart below to track water use throughout one day. Remember to consider indirect water use, like consumption of food that requires water to be produced/grown/cooked and electricity generated by a hydroelectric plant.

Date Data Collected:

Time	Water Use	Water Source

Activity 2: Water Availability

Learning Objective:

Students will learn about changes in water availability on a local and national scale.

Background Information:

Climate change is impacting the water cycle and water systems across the globe. As the average temperature has increased, the EPA has documented some of the following changes in water events (click on links to view data in charts):

- Higher than average and lower than average precipitation
- Increases in river flooding
- Increases in drought conditions

The EPA's Climate Change Indicators Fifth Edition Publication provides a wealth of additional information about the causes and current and future implications of climate change.

When considering how climate change impacts gardens, landscapes and agricultural land, the two water extremes, floods and droughts, are prominent concerns. Both can have severe effects on plant and animal life and their ability to survive and thrive in their ecosystems.

Flooding – The Many Effects of Flooding from National Geographic is an excellent read for students to learn how flooding can have both negative and positive impacts. Flood waters cause erosion and sedimentation, changing both land topography and water pathways. Flooding often results in polluted water and disease. On the benefits side, flooding can bring new nutrients to the soil, refill ground water sources and support wetland habitats.

Droughts – Unlike flooding which is often linked to a specific devasting weather event, droughts usually build over time and with lasting effects. Drought fosters drought because decreased evaporation and transpiration from land surfaces slows the generation of new precipitation, leading to continued dry weather. The National Drought Mitigation Center provides a long list of impacts including loss of crops and habitat, wildfires, and wind-fueled soil erosion. The Dust Bowl is one of the most notable drought events in the United States.

The National Oceanic and Atmospheric Administration (NOAA) has put together a powerful resource at Drought.gov that offers both current and historical climate information documenting drought conditions in the United States. From the National Current Conditions page, you can explore drought monitoring, precipitation conditions, temperature, evaporative demand, and soil moisture conditions. You can even focus in on this information specific to your state and county.

To compare current drought conditions with historical drought conditions, the National Drought Mitigation Center has developed a handy [Drought Comparison Slider Tool](). On this map, you can enter two different dates between 2000 and 2025, one on the left side and one on the right side, and then slide the blue bar across the map to compare drought conditions between the two dates.

Resources:

Climate Change Indicators. EPA. https://www.epa.gov/climate-indicators

The Climate Change Indicators in the United States, 5 Ed. EPA.
https://www.epa.gov/system/files/documents/2024-09/climate_indicators_2024.pdf

The Many Effects of Flooding. National Geographic Education.
https://education.nationalgeographic.org/resource/many-effects-flooding/6th-grade/

How Does Drought Effect Our Lives. National Drought Mitigation Center.
https://drought.unl.edu/Education/DroughtforKids/DroughtEffects.aspx

The Dust Bowl. National Drought Mitigation Center. https://drought.unl.edu/DustBowl/

National Current Conditions. Drought.gov. https://www.drought.gov/current-conditions

Drought.gov is a resource of the NOAA and the National Integrated Drought Information System to provide historical and current data regarding drought conditions available at: https://www.drought.gov/

Educating on a Changing Planet: Drought Resistant and Climate Resilient Strategies For Our Future. This webinar shares a comprehensive middle school garden project on climate change implemented at a school in Arizona. https://sgsonetwork.org/educating-on-a-changing-planet-2/

Materials Needed:

- Venn Diagram Sample
- Drought Maps Worksheet

Instructions:

1. As a class, review the difference between weather and climate. Ask students if they have heard of any ways climate changes can impacting water systems. If they need inspiration for the discussion, share the video: How Do We Know the Climate Is Changing by NASA or read How Climate Change Impacts Water Access by National Geographic.

2. More extreme weather is one of the commonly noted results of changing climate. Too much water (flooding) and too little water (drought) are results of extreme weather challenging our ecosystems. Have students read The Many Effects of Flooding and Understanding Droughts from National Geographic. After reading the two, create a Venn Diagram to compare the similarities and differences between these two phenomena (See Venn Diagram Sample).

3. Next, as a class take a deeper dive into drought by exploring the National Drought Status - National Current Conditions page from NOAA. Explore each of the maps and discuss the:
    a. Drought Monitor Map
    b. Precipitation Conditions Map
    c. Temperature Conditions Map
    d. Soil Moisture Conditions Map

4. At the bottom of the web page, enter your state into the “Explore More Locations” box to investigate local conditions. Working individually or in groups, students can use the maps on the state page to answer the questions on the Drought Maps worksheet.

5. After filling out the worksheet, ask students to reflect on the information they discovered. Do you think this information is useful? How can this help us care for our gardens and landscapes? Are there other indicators that could be used by gardeners to decide if gardens or landscapes need supplemental water? What other data might we look at? Are there other tools we could use? Are there any observations we could to determine water needs?

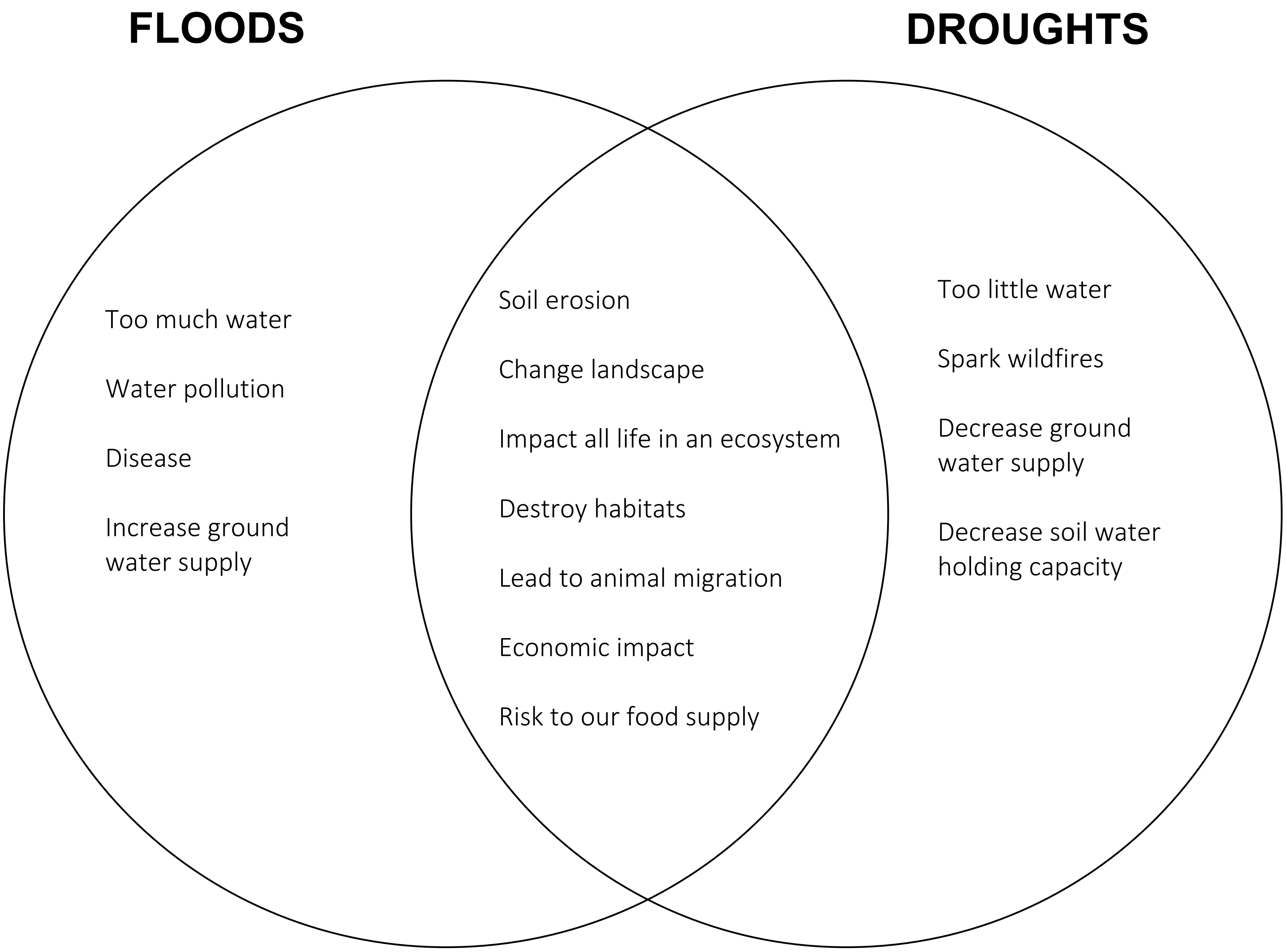
6. Finish the lesson by considering why it is so important to track water availability. Which do you think is harder on plants, floods or droughts? Give students a chance to defend their opinion.

Extend the Learning:

To compare current drought conditions with historical drought conditions, the National Drought Mitigation Center has developed a handy Drought Comparison Slider Tool available at https://droughtmonitor.unl.edu/Maps/ComparisonSlider.aspx. On this map, you can enter two different dates between 2000 and 2025, one on the left side and one on the right side, and then slide the blue bar across the map to compare drought conditions between the two dates. This tool can be used to show how drought conditions change throughout the seasons and have changed over the years.

The EPA also offers informative bulletins about state and regional climate connections at https://www.epa.gov/climateimpacts/state-and-regional-climate-change-connections for students to dive deeper into how climate change is impacting their local ecosystems.

Venn Diagram Sample



Drought Maps Worksheet

Visit the **National Current Conditions Maps** at: https://www.drought.gov/current-conditions and answer the following questions:

1. What percentage of the United States is experiencing drought this week? Is that an increase or decrease over last week?

2. What are some of the states that are experiencing drought at this time?

Next, scroll down to the bottom of the web page, enter your state into the **"Explore More Locations" box** to view state specific maps. Answer the following questions:

3. Is our state experiencing drought? If so, what level drought (D0-D4)?

4. Have we had any rain in the last 7 days?

5. Have we had normal rainfall in the last 30 days? Or last 60 days?

6. What has been our average temperature over the last 7 days?

7. Are any of the areas in our state experiencing unusually hot or cool weather over the last month?

8. How are the soil moisture conditions in our state?

9. Based on this information, do you think we need to water our gardens more or less?

10. What is the future forecast for precipitation and temperature?

11. What is the drought outlook for our state?

Activity 3: Water in the Garden

Learning Objective:

Students will explore how much water is used in gardens and landscapes.

Background Information:

In their native ecosystems, plants and wildlife have evolved so that their water needs closely match water available through ground and surface water sources which are recharged by precipitation (rain and snow). However, gardens, landscapes and agricultural land often include non-native plants and animals that are not necessarily well-adapted to existing environmental conditions. Additionally, rapid changes in temperature and precipitation due to climate change have altered the natural balance of water systems, increasing the difference between available water and water needed by ecosystem inhabitants. To fill in this gap, humans have employed irrigation techniques to supply supplemental water to plants and animals from surface and ground sources when water needs are not being met by precipitation and other natural sources.

As mentioned in Activity 1, irrigation accounts for 37% of withdrawals from surface and ground water supplies (118 billion gallons of water per day). Although irrigation of agriculture land is a large part of this percentage, the EPA estimates that landscape irrigation makes up nearly one-third of all residential water use, coming in at an estimated 9 billion gallons of water per day. These statistics shows that gardens and landscapes play a significant role in our water system too. With increasing demands on clean water supplies, it is of critical importance to use every drop wisely.

To ensure water is being used efficiently, the amount of irrigation water supplied should be as close as possible to the water needed. Understanding the water needs of plants is a critical step in promoting water conservation and planning waterwise farms, gardens, and landscapes.

Although gardeners and farmers can observe plants to look for signs of water distress, scientists have also developed mathematical equations to help understand and predict water needs to inform not only water application for existing spaces, but also to help in plant selection and design. One of those techniques is the SLIDE method (Simplified Landscape Irrigation Demand Estimation).

SLIDE uses the evapotranspiration rate, a plant factor number, and the size of an area to estimate the water demands of a landscaped area. By learning about each of the components of this formula, students can better understand the water needs of their garden.

Evapotranspiration Rate: This rate calculates how much water moves from the soil, through a plant and into the atmosphere. This rate is impacted by sunlight, air temperature, relative humidity and wind speed. As sunlight, air and windspeed increase and relative humidity decreases, the evapotranspiration rate and thus the water needs of a plant will increase. The evapotranspiration can be challenging to calculate. Some weather stations and state agencies will provide this information. There is also a nonprofit organization that tracks rates through citizen scientists that offers some data called The Community Collaborative Rain, Hail and Snow Network.

Plant Factor: Different plants have different water needs. The SLIDE Plant Factor helps take these differences into account. Plants with lower water needs include things like native and adapted plants, succulents, and cacti. Medium plants include many non-native perennials and shrubs. High needs plants include annuals, tropical plants, and fruits and vegetables. The University of California shares the following chart of plant factor numbers (the higher the plant factor number, the more water it needs):

Plant Type	Plant Factor
Tree, Shrubs, Vines, Groundcovers (woody plants)	0.5
Herbaceous Perennials	0.5
Desert Adapted Plants	0.3
Annual Flowers & Bedding Plants	0.8
General Turfgrass Lawns, cool-season (tall fescue, Ky. bluegrass, rye, bent)	0.8
General Turfgrass Lawns, warm-season (bermuda, zoysia, St, Augustine, buffalo)	0.6
Home Fruit Crops, Deciduous	0.8
Home Fruit Crops, Evergreen	1.0
Home Vegetable Crops	1.0

Space: The final component of SLIDE calculation is the area of the landscape. The size of the landscape and total number of plants living in the space and volume of soil will impact the amount of water needed.

Resources:

Summary of Estimated Water Use in the United States in 2015. USGS.
https://pubs.usgs.gov/fs/2018/3035/fs20183035.pdf

Outdoor Water Use in the United States. EPA.
https://19january2017snapshot.epa.gov/www3/watersense/pubs/outdoor.html

Using SLIDE to Estimate Landscape Water Requirements. Center for Landscape & Urban Horticulture, University of California. https://ucanr.edu/site/center-landscape-urban-horticulture/using-ansi/asabe-s623-slide-estimate-landscape-water

ET: Evapotranspiration and Plant Water Use. Center for Landscape & Urban Horticulture, University of California. https://ucanr.edu/site/center-landscape-urban-horticulture/et-evapotranspiration-and-plant-water-use

ET Reports. Community Collaborative Rain, Hail & Snow Network. https://www.cocorahs.org/ViewData/ListETReports.aspx

The University of California has developed many resources as part of their Center for Landscape & Urban Horticulture to help understand landscape water needs at: https://ucanr.edu/site/center-landscape-urban-horticulture.

Materials:

- Marking flags
- Journal
- Pencils
- Phone or tablet with Seek app by iNaturalist (optional)

Instructions:

1. Visit a landscape or garden space during the hottest time of the day, if possible when it has been a while since it has rained and/or been watered. Give students a couple of marking flags and ask them to walk around and place a flag in front of any plant that is showing signs of water stress such as wilting leaves or drooping stems. Ask them to make observations about at least one of the water-stressed in plants using the Water Needs Observation Sheet.

2. After they have had time to make observations, come together as a group and ask:
   - Did you find plants that look like they need water?
   - Are all the plants in the garden/landscape showing water stress?

3. Visit the plants showing signs of water stress together as a group and let students share their observations. Did the plants identified have any similarities? Differences? Was the soil wet or dry? Note: If the soil was wet indicating water was available, make sure to have them brainstorm why they think some plants may have been showing signs of water stress. Common reasons include the speed of transpiration and root problems. On a hot, dry and windy day, some plants may not be able to take up water as fast as it is leaving the plant through transpiration. Also, plant roots can be impacted by disease problems, decreasing the amount of the water they are able to absorb.

4. Based on these observations, ask students to brainstorm a class list of factors that might impact how much water plants need. If the list does not include all the factors mentioned in the background information, add them to the list, making sure to cover sunlight, air temperature, relative humidity, wind speed, plants' individual water needs, and size of garden. Ask, What do we do when plants' water needs do not match water availability?

5. Share background information about how much water we use for irrigation. Looking at the list of these factors, are there any we can control/change to help us use less supplemental water? Students should arrive at the idea that plant selection and size of garden/landscape are the two we have the most control over (although there are some techniques that could be used to help influence some of the others too). Share the list of plant factors and discuss how some plants are better adapted to the water naturally available in an ecosystem, including native plants.

6. Ask students to find and research a plant that is well adapted to the water conditions in your area. Your state's native plant society may be a good place to start and can be found through the North American Native Plant Society's website at https://nanps.org/native-plant-societies/.

Extend the Learning:

The EPA has developed a Water Budget Tool available at https://www.epa.gov/watersense/water-budget-tool to help estimate the water demands of a landscape. By entering your zip code, the size of your garden, and defining what type of plants are found in the space into a spreadsheet, you can receive an estimate of how many gallons of water per month will be needed. This tool can be used for an existing space or for landscape plans to determine estimated water needs. Although this tool was designed for irrigation and landscape professionals, a demonstration of the tool for students can help them further understand the how important plant selection in gardens and landscapes for efficient use of water.

Water Needs Observation Worksheet

Find a plant showing water stress and complete the following:

Plant Name (*): *use an ID app like Seek by iNaturalist to identify if needed		
Circle one answer from the following:		
Type of Plant:	Size of Plant:	Sun Exposure:
Annual Perennial Grass Shrub Small Tree Large Tree	Small Medium Large	Full Sun Part Sun Shade
What is the temperature?	Is it windy?	How does the soil feel?
Cold Cool Warm Hot	No wind A little wind Medium wind Lots of wind	Dry Moist Wet
What signs of water stress are you noticing:		
Are the plants around your plant showing signs of water stress:		Yes or No
Why do you think this plant is experiencing water stress?		

Module 3 Next Generational Science Standards

The following standards inspired the activities in this Waterwise Garden Stewards module:

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Waterwise Garden Stewards
Module 4: Waterwise Landscape Design

Learning Objectives

Careful design of garden and landscape spaces is critical to ensuring water from rainfall and supplement irrigation is used efficiently. This module introduces students to elements that help create a waterwise landscape. Students will:

- Learn about basic garden design techniques that promote water conservation.
- Explore garden themes that focus on water efficiency including xeriscapes and rain gardens.
- Use new knowledge to design a waterwise garden.

Activity 1: Water Conservation in the Garden

Learning Objective:

Students will learn about basic garden design techniques that promote water conservation.

Background Information:

Waterwise gardening begins before the first plant ever goes into the ground. Thoughtful planning of garden's landscape design and plant selection will help use water efficiently. Here are some foundational water-saving planning and design considerations:

Carefully select planting locations. Before deciding on a planting location, it is important to observe the way the site slopes and take note of where water naturally flows downward after rainfall. This is the first step to ensuring that plants can meet as much of their water needs from rainfall as possible. Place plants with higher water needs at the base of the slope and more drought-tolerant ones higher up the slope. Choosing locations where plants are protected from direct sun during the hottest part of the day reduces water loss. Windbreaks protect plants from drying winds.

Know (and improve) your soil. Clay soils are slow to absorb water, but they tend to hold moisture longer and can become oversaturated. Sandy soils drain quickly, so they dry out faster. Positioning gardens in areas with loamy soils (a mix of sand, silt and clay) is optimal. Alternately, sandy or clay soils can be improved by adding compost. Organic matter like compost improves water infiltration in clay soils and boosts water-holding capacity in sandy soils.

Contour land if appropriate. Moving soil to create swales and berms will direct the flow of water and allow more rainfall to reach the garden, while also decreasing the amount of water going into storm drains and sewers. A berm is a mound of soil while a swale is a depressed area; both help direct rainwater flow. For best use of these features, water should not be directed away from natural areas that may rely on the rainwater, rather they should be used to redirect water that is being 'wasted' by being carried across paved areas and into man-made drainage systems.

Select the right plants. Different plants require different amounts of water. Gardeners who want to lower supplemental water needs should consider plants that are native to or naturalized in their local environment. Native plants are usually well adapted to the natural rainfall in their ecosystem, so once established in the garden, they'll be able to meet most of their water needs from rain during a typical year.

Plant in zones. Group plants with similar water needs together. That way, it's easier to water all the thirsty plants more frequently than those with lower water needs.

Install efficient irrigation. Planning the irrigation system at the same time as you design the garden and landscape can inform some key design decisions including size, shape and location of garden beds.

Install a rain barrel. Rain barrels are designed to capture the rain so you can save it for future use. To capture the most rain, rain barrels are often placed at the end of a gutter downspout to take advantage of the surface area of a roof. Note: It's generally not recommended to use rain barrel water on edible plants, as it may hold chemicals or debris from the roof.

Consider alternative growing techniques. When considering water-efficient gardening techniques, thinking beyond traditional gardens can also provide solutions. For example, hydroponic gardening is a technique in which nutrients are supplied to plants via their water supply rather than through the soil. Hydroponic systems are designed to capture and reuse water, so the only water lost is that which the plants absorb and need for healthy growth. They are water-efficient and typically use less water than traditional growing systems where water is lost to runoff and evaporation. Growing plants hydroponically allows gardeners to grow in smaller areas, such as greenhouses, living rooms, classrooms, and rooftops. There are some challenges when using hydroponic systems. Most require a continuous energy source and specific equipment to support the delivery of water and nutrients. Additionally, only select plants are well-adapted to growing in hydroponic systems.

Resources:

Water Your School Garden Tip Sheet. KidsGardening. https://kidsgardening.org/wp-content/uploads/2024/10/Watering-Your-School-Garden-Tip-Sheet.pdf

EPA Water-Smart Landscapes. EPA. https://www.epa.gov/sites/default/files/2017-01/documents/ws-outdoor-water-efficient-landscaping.pdf

Materials:

- Site Analysis Worksheets
- Clipboards
- Pencils
- Large tape measure (or string and meter stick or ruler)

Instructions:

1. One of the first steps to designing a garden is to conduct a site analysis. This process helps determine the location of the garden and evaluate the potential location's existing conditions. Ask students to brainstorm why this step might be important if you want to plan a waterwise garden. Share that choosing a favorable site can help you maximize water efficiency and the findings can influence design considerations and plant selection.

2. Give students a copy of the site analysis worksheet, a clipboard and a pencil. Go over each step of the site analysis process in the classroom which includes:
    a. Creating a bird's eye view sketch of the space.
    b. Noting how the space is currently used
    c. Making observations about the land, water availability, sun exposure, soil condition, accessibility, and other features.

3. Visit an outdoor space that could serve as a potential waterwise garden site (could be a brand new garden or a garden renovation). In addition to the site analysis worksheets, you will need a large tape measure or, if not available, you can mark distances using string and then convert to measurement using a meter stick or ruler. Depending on the skill level of your students, you can work as a class to complete one site analysis together or students can work in teams or independently. You can also choose to have all groups focus on one location or investigate multiple spots if logistically feasible.

4. Have students complete the site analysis worksheet.

5. When finished, come together as a group and discuss findings or share findings (if worked in groups). Make sure to specifically emphasize findings related to water access and availability. Create a list that notes the traits of the space that would be helpful for creating a waterwise garden (such as land contoured to capture rainfall, proximity to a water source, or existing loamy soil) and traits that might make it more challenging (such as sandy soil, no water access, or in full sun at the peak of the day). Share the design techniques from the Background Information to help students evaluate waterwise traits.

6. If you have investigated one space, decide as a group if this site is a good choice for a waterwise garden. If it is not a good choice, consider investigating other spaces. If students have evaluated multiple sites, have the class vote which one they think is the best choice.

7. Save site analysis worksheet and site measurements for Activity 3.

Garden Site Analysis Worksheet

Gather the following information to help plan your future waterwise garden:

Sketch the potential site from a birds' eye view in the space below.

Measure the parameter of the space and include any existing features you plan to keep like large trees, existing planting beds and sidewalks. Include measurements between major features that can be used to create a site map later. Make a note of water sources.

Answer the following questions about your site:

1. Describe where the site is located (ex. In a courtyard, on a playground, on top of concrete, etc.):
2. How is the site currently being used?
3. Who will visit the garden?
4. What are the goals for the garden?
5. How many months out of the year will the garden be used?
6. How much time will be available for taking care of the garden?

Site Viability Checklist

Land	Yes	No	Notes
Are there utilities (plumbing, electrical, etc.) we need to avoid in the space?			
Are there steep slopes? Will we need to take measures to prevent erosion?			
Are there places where you can see standing water after it rains?			
Are there any trees nearby that may have roots underground?			
Does the ground have any unusual dips?			
Is wind a problem? What direction does the wind blow most often?			
Is there anything currently planted on the site (existing plants, weeds, or grass)?			

Water	Yes	No	Notes
Is there a close water source? What type? Distance? Is a key needed to turn the water on?			
Sun	**Yes**	**No**	**Notes**
Is there sufficient sunlight in the space? How much? Is it less than, equal to or more than 8 hours a day?			
Does the site receive sunlight all through the day or just in the morning or afternoon?			
Will light availability change during the year?			
Will other buildings, structures, or trees that will cause shade? At what time of the day?			
Accessibility	**Yes**	**No**	**Notes**
Is the space close to the building? Distant?			
Is it easy to access the site? Is it near a path? How frequently will the site be visited?			
Is the space accessible to those with disabilities?			
Is there a place to sit?			
Is there a shady place to rest when it is hot or raining?			
Is there a drinking fountain or water bottle filling station nearby? A restroom?			
Is the space safe and secure? What surrounds the space? Do you want to block any views, such as a busy road or dumpster?			
Is the proposed garden space near a play area or a high-traffic zone? Will people be apt to walk/run through the garden?			
Does the space have animal pests like deer?			
Is vandalism an issue?			
Can deliveries be made to the space? Ex.: soil, plants and mulch.			

Soil	Yes	No	Notes
Do you want to plant directly in the existing soil?			
Have you conducted a soil test?			
What is the soil texture? Is it sandy? Or heavy with clay?			
Does the soil contain any contaminants, like lead?			

Design Preferences

Add notes about any features you wish to add to your design in the categories listed below:

Feature	Notes
Type of Garden Beds (raised beds, containers, elevated beds, in-ground beds, indoor gardens, hydroponic gardens, other)	
Plants (fruits, vegetables, herbs, native plants, pollinator plants, ornamental, other)	
Pathway Materials (concrete, crushed granite, asphalt, gravel, mulch, brick, other)	
Pathway Edging (landscape timbers, bricks, plastic, other)	
Entries and Exits (pathway opening, arbor, gate, other)	
Sitting Areas (benches, picnic tables, chairs, stumps, portable stools, portable tables, other)	
Shade Structures (shade sails, tents, shade umbrellas, trellis/arbor, gazebo, trees, other)	
Storage (shed, containers, other)	
Fencing (wood, metal, plastic, other)	
Irrigation (hose, soaker hoses, drip irrigation, rain barrel, other)	
Signage (welcome sign, signs for sponsors/donors, garden rules, educational, plant labels, other)	
Educational and Play Stations (outdoor classroom, whiteboard, compost bin, little library, potting table, worm viewers, root viewers, forts/nooks, bird houses/roosts, other)	
Season Extensions and Plant Supports (greenhouse, frost covers, shade covers, tomato cages, other)	

Activity 2: Water Efficient Garden Design

Learning Objective:

Students will explore garden themes that focus on water efficiency including xeriscapes and rain gardens.

Background Information:

Due to increasing weather extremes, the times when gardens have too much or too little rain water are becoming more frequent. Landscape designers have developed two types of gardens to help with water efficiency for both extremes – rain gardens and xeriscapes.

Rain Gardens. Rain gardens are planted in sunken or low-lying areas that naturally collect water. This design allows them to trap and store stormwater before it causes erosion or runs off into storm drains or sewer systems. As the water slowly filters into the garden, soil and plants help remove pollutants and prevent them from entering waterways. It's important to select the right plants for rain gardens, as they'll experience excess moisture and increased levels of nutrients often found in stormwater runoff. Tough, native plants that can handle periods of dry and wet soil will do best. Rain gardens are most useful if situated downhill from impermeable surfaces, such as rooftops and roads, to collect runoff. They can also benefit from a thick layer of mulch to help prevent erosion and keep soil moist during dry periods. Rain gardens are a good landscape solution for locations that regularly receive significant amounts of rainfall at one time. Learn more.

Xeriscapes. A xeriscape (ZARE-eh-scape or ZEER-eh-scape) is a landscape that is designed to reduce the need for irrigation or other supplemental watering beyond what nature provides. Although commonly associated with desert climates, xeriscaping principles can be applied to landscape design in any climate. Coined in the 1980s by Denver Water, a public water utility, the term xeriscape derives from the Greek prefix xeros, meaning dry. The concept was introduced as a way to help residents use less water while maintaining an attractive landscape. It also offers alternatives to the notion that a well-maintained landscape must include expanses of manicured (and thirsty) lawns. Xeriscape design focuses on proper soil improvements, use of plants with low water needs (most often native plants), planting in zones, installation of efficient irrigation, extensive use of mulch to increase water retention and decrease evaporation, and limiting use of turf areas. Xeriscapes are good landscape solutions for locations where rainfall is limited. Learn more.

Resources:

Conserving Water with Xeriscaping Techniques: https://kidsgardening.org/resources/digging-deeper-xeriscaping/

Rain Gardens: https://kidsgardening.org/resources/lesson-plans-rain-gardens/

Materials Needed:

- Waterwise Garden Research Worksheet
- Pencils
- Computers with presentation platforms (i.e., Powerpoint, Google Slides, Canva)

Instructions:

1. Rain gardens and xeriscapes are two design solutions to help gardener's use water efficiently. Share a brief overview of both with students, noting that rain gardens help capture water so that it can be slowly absorbed into the soil and xeriscape design principles help minimize the need for supplemental water.

2. Divide students into two or more groups (depending on class size and desired group size). Ask one (or half) of the groups to research rain gardens and the other group (or groups) to research xeriscapes. If you would like to provide or suggest resources to help them get started, you may want to share:
   a. Colorado State University: The 7 Principles of Xeriscape Landscaping at https://engagement.source.colostate.edu/7-principles-of-xeriscaping-horticulture-expert-explains/
   b. GreenCO Colorado: Xeriscape is Not a Garden, It's a System at https://www.youtube.com/watch?v=knpuK6nKvkQ
   c. Groundwater Foundation: All About Rain Gardens at https://groundwater.org/rain-gardens/
   d. Nature Works: Design and Build a Rain Garden for Your School or Community Video at https://vimeo.com/234213950

   They can use the Waterwise Garden Research Worksheet as a guide.

3. Ask each group to create a short presentation summarizing their findings and give them time to share with their classmates.

4. After the presentation, reflect on how each of these design solutions help conserve water in a garden and landscape. How are they similar? How are they different?

5. Next, ask students to reflect on the site analysis they conducted in Activity 1. Ask them to consider the following:
   - How much rainwater do we usually get? If they do not know, you may want to look up your area's historic rainfall using the National Weather Service's Climate Information. Visit: https://www.weather.gov/wrh/climate and then click on your area to arrive at the data search tool. In the search tool: #1. Select the closest area to your location, #2. Select Daily/Monthly Normals, #3. Select Monthly Precipitation and then click on #4. Hit "Go" and you will arrive at a bar graph of the average precipitation over the time that data has been collected.
   - Do we tend to have heavy rain or light rain?
   - Does water collect in our proposed site or does it run off into another location? (If possible, take a trip to see the site during and after a rain to observe water pattern.)

- Do we regularly experience drought conditions?
- Based on this information, do you think either of these design techniques work well in our site? If yes, which one do you think would be best for our site? Do you think these gardens would be a solution for helping minimize human impact on our environment?

Extend the Learning:

Share Your Presentations: Class presentations can be adapted to serve as an educational resource for your whole school and community. Look for opportunities for students to share research findings with a broader audience.

Waterwise Garden Research Worksheet

Design Topic (circle one): Rain Gardens or Xeriscape

1. Design definition:

2. Benefits of your garden design:

3. Important components of your garden design:
    1.
    2.
    3.

4. Types of plants used in your garden design:

5. Additional notes:

6. Resources used:

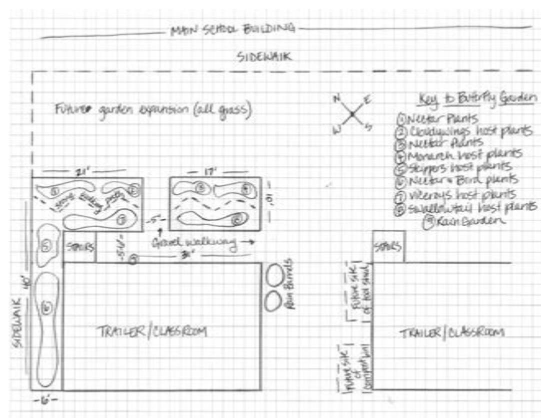
Activity 3: Designing a Waterwise Garden

Learning Objective:

Students will use new knowledge to design a waterwise garden.

Background Information:

A waterwise garden or landscape is a growing space that tries to match plant water needs to natural water availability as closely as possible, and when supplement water is needed, relies on efficient irrigation delivery. By their very definition, waterwise gardens will vary greatly in appearance depending on the ecosystem they are located in. The EPA offers a photo gallery of WaterSense gardens from around the country to show the diversity of designs.



In this activity, students will engage in creating their own waterwise garden design. You may want to review the Background information from Activity 1 with students to help with this activity. Other resources that you may find very helpful to support student designs include:

- EPA's What to Plant – This page offers a catalog of plant databases which can be sorted by state.
- North American Native Plant Society – Native plants are frequently used in waterwise designs and this page provides an index of local- and state-based native plant organizations.
- Cooperative Extension Office – You can contact your local extension office to search for waterwise resources and support organizations in your area. Waterwise gardening is a topic of focus for all land grant universities and there is a wealth of local information for you to uncover.

Resources:

WaterSense Landscape Photo Gallery. EPA. https://www.epa.gov/watersense/landscape-photo-gallery

What to Plant. EPA. https://www.epa.gov/watersense/what-plant

Native Plant Societies. North American Native Plant Society. https://nanps.org/native-plant-societies/.

Find Extension in Your State. Extension Foundation. https://extension.org/find-cooperative-extension-in-your-state/

Designing and Placing the Garden: https://kidsgardening.org/resources/designing-a-school-garden-designing-and-placing-the-garden/

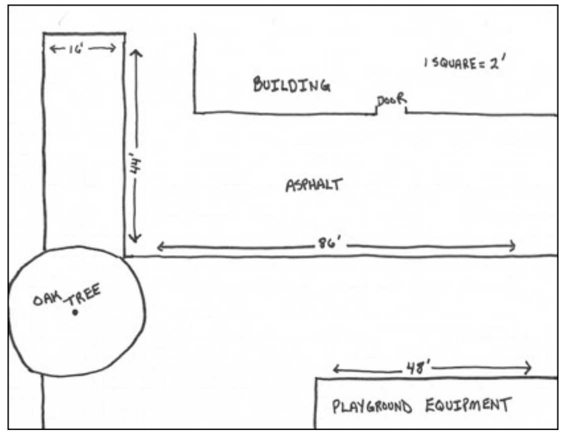
Materials:

- Graph paper
- Pencils
- Internet access or plant books/catalogs

Instructions:

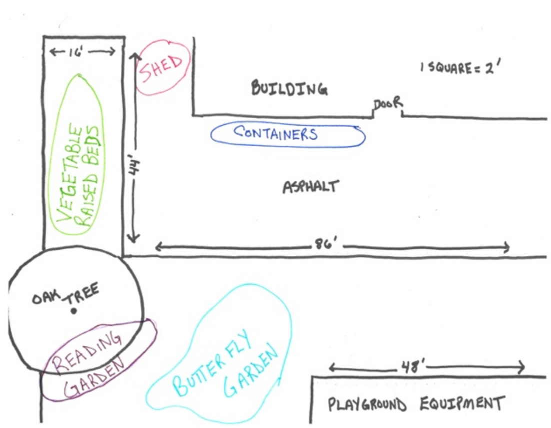
1. Students will use their site analysis from Activity 1 and research from Activity 2 to create their own waterwise design. They can work individually or in groups.

2. **Make a base map.** The first step is to take the measurements from their site analysis and create a base map. Have students sketch the birds' eye outline of their garden space to scale using graph paper. Make sure they include the perimeter of the space along with any hardscape or plant materials that will not be moved.



3. **Summarize needs and conditions.** Next, ask them to create a list of ideas and goals for the garden based on the observations and identify needs. For instance, if the garden will serve as an outdoor classroom space, the garden probably needs seating. If the garden is in a shady area, plants must be shade tolerant.

4. **Create Bubble Diagrams.** With base map and needs list in hand, next up is brainstorming. Many landscape designers brainstorm by using bubble diagrams. Bubble diagrams define open spaces using roughly drawn circles, squares and other shapes rather than trying to determine specific sizes for the different areas. The advantage is that you can draw bubbles quickly, experimenting with different configurations, and can use different colors for clarity. An easy way to do this is by laying pieces of tracing paper over the original base map. Another approach is to make copies of the base map and ask students to each come up with a possible design.



Guide them to draw in bubbles for each major space they want to include such as a vegetable garden, a rain garden, a seating area, pathways, etc. They will want to create multiple configurations with each version trying out different arrangements (such as placing the sitting area in the center versus the side), shapes (circular beds versus rectangular beds), and sizes (e.g., a few large garden beds versus multiple small beds) until you develop a general idea of where you want to place the different components.

5. **Define Beds and Hardscapes.** Once they have a rough idea of placement they think will work, then it is time to dig into more detail. Suggest that they start by defining beds, walkways, and any other paved areas. They can also draw in other hardscape elements and prominent features such as sitting areas, water features and storage.

6. **Identify Their Plant List.** Lastly, they can use the plant databases mentioned in the Background Information to recommend plant materials. Remind them that for a waterwise garden, they need to choose plants that can grow successfully in your region using rainwater and irrigation water efficiently.

7. **Share Design Plans.** Once designs are done, place them on display and let students present their ideas to classmates. If you have the opportunity to install the garden, you may want to choose from the plans or create a new plan that incorporates the best ideas from the plans.

Extend the Learning:

Create a Garden Work Plan. Whether you will be installing the garden or not, creating a detailed installation plan can help students look critically at the design. They can complete further research to better understand soil preparation and construction techniques. They can also estimate costs and practice making a budget.

Module 4 Next Generational Science Standards

The following standards inspired the activities in the Waterwise Garden Stewards Unit:

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

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.

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.

Waterwise Garden Stewards
Module 5: Irrigation Design

Learning Objectives

Plants aren't the only organisms that rely on the water found in soil. The soil biome is home to millions of other organisms that also need adequate moisture to survive. Properly hydrated soil is the foundation for life ecosystems both below and above ground. When soil is too dry there can be devasting consequences, including widespread plant and organism death, erosion and wildfires. For thousands of years, humans have crafted ways to provide water to land in times of inadequate rainfall. With a changing climate, efforts to develop irrigation techniques that deliver supplemental water efficiently are increasingly important. In this module, students will:

- Learn about the history of irrigation.
- Explore and compare common irrigation techniques and equipment.
- Compile information needed to aid in selection of an irrigation system.

Activity 1: Supplemental Irrigation

Learning Objective:

Students will learn about the history of irrigation.

Background Information:

Humans have long recognized the need to provide supplemental water to land, especially for edible crops. The earliest attempts at irrigation may have been the creation of basins surrounded by mounded earth to capture rainwater for later use. Historical records indicate the use of irrigation practices in:

6,000 BCE – in Egypt in the Nile River basin
4,000 BCE – in Mesopotamia in the Tigris and Euphrates River basins
3,000 BCE – in China in the Yellow River basin
2,500 BCE – in India in the Indus River basin

Various irrigation techniques were practiced by the Maya and Inca civilizations as well as in Japan and in Europe. In North America, irrigation is known to have been used by southwestern Native Americans as early as 1,200 BCE using canals to divert water from rivers. Irrigation waters were originally drawn primarily from surface water sources; however, use of underground water sources from aquifers expanded greatly in the 1900's.

The [Irrigation Systems Management]() publication from The American Society of Agricultural and Biological Engineers shares the following statistics adapted from FAO publications showing the growth in irrigation over the last century:

Growth of Irrigated Land and World Population

Year	Irrigated Land (millions of acres)	Population (billions)
1900	100	1.5
1950	235	2.5
1970	422	3.7
1990	598	5.3
1997	669	5.9
2017	806	7.5

Top 10 Irrigated Countries in the World in 2017

Country	Irrigated Land (millions of acres)	Population (millions)
India	174	1,339
China	173	1,453
United States	66	325
Pakistan	49	208
Iran	22	81
Indonesia	17	265
Thailand	16	69
Mexico	16	125
Turkey	13	81
Brazil	11	208

As the numbers indicate, as population size grows, food demands also grow, thus leading to an increase in the amount of irrigated land. In addition to irrigation used for edible crops, remember from Module 3 that there has also been an increase in irrigation used on residential landscapes that is not reflected in these numbers.

Resources:

Irrigation Systems Management. Dean E. Eisenhauer, Derrel L. Martin, Derek M. Heeren, Glenn J. Hoffman. American Society of Agricultural and Biological Engineers. 2021.
https://asabe.org/portals/0/apubs/books/ism/irrigationsystemsmanagement.pdf

Materials:

- Irrigated Land Data Worksheet
- 9" x 13" baking pans or disposable aluminum pans
- Paper bowls (about the same depth as the baking pan if possible)
- Soil
- Paper
- Pencils
- Water
- Scissors
- Assorted craft supplies including at minimum straws and toothpicks

Instructions:

1. Ask students to reflect on different ways gardeners and farmers get water to their plants when there is not enough rainfall. Why is it so important for the soil to stay moist? What happens when soil gets too dry? Make sure to discuss how soil moisture is important to plants and all life living in the soil. When the soil does not maintain proper moisture, it can result in death of both plants and other organisms and can lead to soil erosion. Frequent drying of the soil can also impact its structure and ultimate water-holding capacity. Just like a sponge that has been dry for too long, soil that becomes too dry between waterings will have a decreased ability to hold water.

2. Introduce that the need to provide supplemental water is not a new phenomenon. Share information about historical irrigation use from the Background Information. You can also share with them the video [Ancient Irrigation Systems](https://www.youtube.com/watch?v=E6tiupLHnqg) from the Daily Bellringer available at https://www.youtube.com/watch?v=E6tiupLHnqg.

3. Share the Irrigated Land Data Worksheet with students (either as a handout or projected to a screen). Lead students in discussion by asking, how has irrigation changed of the years? Why do you think it has changed? Do you think the amount of irrigated land is going to increase or decrease in the future? If water supplies are limited and yet the amount of irrigated land is increasing, what can we do to decrease water use? Why is it so important for us to develop efficient irrigation systems?

4. Next, give students a chance to think about irrigation systems. Divide the class into groups and give them each a baking pan, paper bowl and soil. Ask each group to make their own mini landscape by placing the bowl in their pan and then fill up the remaining space with soil. Explain that the bowl is going to represent a surface water source and the soil will represent farm or garden land.

5. With their mini landscape constructed, ask each group to design an irrigation system that would move water from the bowl and moisten the soil throughout the pan. They should sketch out their design on paper and create a list of craft items they think they can use to construct a prototype. Some possible ideas might include: selective cuts in the paper bowl so that water can stream into the soil, raising the bowl and using straws to direct the water throughout the pan, digging a series of canals into the soil.

6. Have students bring in the craft items or provide a class supply (if you plan to provide a class supply, you may want to provide a list of what they can choose from in Step 4).

7. Construct irrigation for the mini landscape from the designs. Give each student a chance to share their system with the class and then fill the bowls with water. Evaluate how well the water is transported to the soil and let students reflect on their system.

8. Once everyone has had a chance to share, brainstorm a list of techniques that worked and those that did not work. Ask for takeaway lessons that they feel they can transfer to the garden.

Water Experiment Observation

Data sourced from The Irrigation Systems Management publication from The American Society of Agricultural and Biological Engineers (https://asabe.org/portals/0/apubs/books/ism/irrigationsystemsmanagement.pdf).

Growth of Irrigated Land and World Population

Year	Irrigated Land (millions of acres)	Population (billions)
1900	100	1.5
1950	235	2.5
1970	422	3.7
1990	598	5.3
1997	669	5.9
2017	806	7.5

Top 10 Irrigated Countries in the World in 2017

Country	Irrigated Land (millions of acres)	Population (millions)
India	174	1,339
China	173	1,453
United States	66	325
Pakistan	49	208
Iran	22	81
Indonesia	17	265
Thailand	16	69
Mexico	16	125
Turkey	13	81
Brazil	11	208

1. How has the amount of irrigated land changed of the years? Why do you think it has changed?

2. Do you think the amount of irrigated land is going to increase or decrease in the future?

3. Why is it so important for us to develop efficient irrigation systems?

Activity 2: Irrigation Basics

Learning Objective:

Students will explore and compare common irrigation techniques and equipment.

Background Information:

There are many different ways to deliver supplemental water to plants. The most common methods include hand watering, sprinklers, and drip irrigation.

Hand Watering

Hand watering is usually the cheapest in terms of equipment costs. By using proper techniques, it can be an efficient use of water. As you use a hose or watering can to irrigate, you can be selective, watering each plant or plot as needed. You can monitor how far moisture soaks into the soil and adjust your watering time as necessary. It's important to apply water directly to the soil beneath the plants and to avoid excessive runoff onto sidewalks and other paved surfaces.

Choose the watering can size based on the size of the gardener. A gallon of water weighs 8 lb, so cans get heavy quickly! Fortunately, watering cans are available in many different sizes. Or you can save money by making your own, such as by using half-gallon or gallon milk and juice jugs with handles.
Hand watering also includes using hoses. A hose with an adjustable spray nozzle allows you to choose the best spray pattern as well as increase volume and water pressure to best suit your needs.

The downside of hand watering is the time and effort needed. Plants need water when they need water, so you'll need to work on their schedule, not yours. This can be challenging, especially during vacation breaks.

Sprinklers

Compared to hand watering, sprinklers decrease the time and effort needed for watering and help deliver consistent moisture in gardens to promote healthy plant and crop production. Some sprinklers can be attached to the end of a hose; others are more sophisticated systems with underground pipes connected to spray heads. When using sprinklers, it's important to keep a careful watch on where the water is going and when it's applied. Water that's sprayed into the air can be lost to evaporation and wind drift. It can also be difficult to adjust spray patterns to avoid overwatering some plants while underwatering others. In addition, it's crucial to avoid wasteful overspray onto non-garden areas, such as sidewalks. Sprinklers can be an effective option if used with care.

Hose-end sprinklers are the least expensive option and can be a good choice if you have lots of beds scattered around. Some produce a spray that moves in a circular motion, while others cast a fan that can move back and forth. You can turn them off and on by hand or purchase a timer to do it for you. The first time you operate your sprinkler, observe the spray pattern to make sure it's applying water where you need it and not onto paved surfaces.

Built-in sprinklers use underground pipes and spray heads. They tend to be more complex to use and cost more to install, but they are very useful for permanent garden beds. There are many different types of spray heads available, including pop-ups, rotors, and bubblers, that allow you to choose the direction and quantity of water delivery. It's a good idea to consult facilities staff and irrigation professionals when installing a permanent sprinkler system.

Automatic timers allow you to program the system to water at the most appropriate time of day while delivering the adequate quantity of water — even if you're away. Some timers even feature a rain sensor that prevents sprinklers from activating during rain! Although automatic timers offer convenience, they can also lead to wasted water if not monitored properly. To prevent this, make sure to check automated sprinkler systems regularly for broken sprinklers, overspray onto paved areas, and overlapping spray that may be overwatering some plants.

Drip Irrigation and Soaker Hoses

Drip systems are a happy medium between hand watering and sprinklers. Drip irrigation offers many benefits over sprinklers. It slowly delivers water right to the soil, minimizing water loss due to evaporation, wind, and runoff. It also keeps foliage dry, minimizing disease problems. Like sprinklers, drip systems can be automated with timers and moisture monitors.

Though a drip system is more expensive than a hose and watering can, it can be less expensive than installing an underground sprinkler system. By saving you both time and water, these systems can give you a rapid return on your initial investment.

Soaker hoses and drip tape: Soaker hoses apply water through small pores, allowing it to soak in from the soil surface. They're a sufficient and low-cost option for rows and beds of vegetables and annual plants, but they don't distribute water evenly. Soaker hoses can be installed in various patterns within a garden space, from winding shapes to straight rows.

Similarly, drip tape releases water through slightly larger, manufacturer-cut holes when it expands into a tube under pressure. Spaced at regular intervals, these holes are less likely to clog in regions with mineral-rich water but need to be replaced seasonally. Soaker hoses and drip tape are typically not pressure-compensating, which means more water is applied closer to the water source than toward the end of the hose. This may result in uneven garden bed watering. Irrigation controllers can be used to manage and automate irrigation for both soaker hoses and drip tape systems.

Emitter hoses: These feature components that are calibrated to deliver precise amounts of water. Some have pipes with built-in emitters; others have flexible tubes that allow you to configure the emitters to deliver water right under individual plants or in pots. Both options deliver water with less chance for water loss due to wind and runoff and can be attached to timers and moisture monitors for increased flexibility in scheduling. By delivering water directly to the soil, they are more selective than a sprinkler but not quite as targeted as hand watering.

Point-source drip emitter irrigation: Point-source drip emitter irrigation slowly delivers water directly to the soil at the base of plants, minimizing water loss from evaporation and wind drift. Individual drip emitters, connected to distribution tubing, are installed throughout the garden space at the base of plants. This allows for flexibility in both plant type and spacing. These drip emitters can be custom-spaced, ensuring that only areas requiring water are irrigated and that plants with higher water needs can receive additional drip emitters. Drip systems generally reduce water splash on plant leaves, which helps lower the risk of disease. Though a drip system is more expensive than a hose and watering can, it's far less costly than installing an underground sprinkler system. Like sprinklers, irrigation controllers may be added to drip systems to provide automated irrigation to garden beds.

Inline drip tubing: Inline drip tubing combines the technologies of drip emitters and soaker hoses, offering a highly efficient irrigation solution for garden beds. Drip emitters are preinstalled inside a flexible distribution tube at specific intervals to provide even water application throughout the garden bed. This design not only enhances irrigation efficiency but also reduces installation and maintenance requirements as the emitters are safely enclosed and less prone to damage from gardening activities. Inline drip tubing is quite flexible and can be installed in rows, winding shapes, or circular shapes. The addition of a programmable irrigation control also adds automated irrigation scheduling to ensure soil moisture levels remain consistent for healthy plant growth.

Olla Pots

For thousands of years, people have buried these porous, clay pots in the soil and filled them with water. This ancient form of drip irrigation allows the water to slowly seep into the soil, where it's available to nearby plants. Although this provides an excellent education opportunity for students, this method of irrigation is impractical for larger garden beds and requires regular attention for hand filling.

Resources:

Watering Your School Garden Tip Sheet. KidsGardening. https://kidsgardening.org/wp-content/uploads/2024/10/Watering-Your-School-Garden-Tip-Sheet.pdf

Materials Needed:

- Watering can
- Example of a sprinkler irrigation system
- Example of a drip irrigation system
- Irrigation Comparison Worksheet

Instructions:

1. Introduce students to the equipment most commonly used for irrigation of a garden or landscape including examples of a watering can, sprinkler, and drip irrigation. If possible, provide students with a live demonstration of each. If that is not possible, you can use clips from the following videos from Hunter Industries to demonstrate:

- Sprinklers:
  - Hunter MP Rotator Sprinkler Overview: https://www.youtube.com/watch?v=vj_3ifs16Cs
  - Hunter Pro-High Efficiency Nozzles Product Guide: https://www.youtube.com/watch?v=UYSRCn1vJU0

- Drip Irrigation:
  - Hunter Dripline Featuring Copper-Infused Emitters: https://www.youtube.com/watch?v=Sc1aLLG-hJc
  - Hunter Dripline – See Why It's the Professional's Choice: https://www.youtube.com/watch?v=fGeltVoe4pE

2. After the demonstration, discuss the irrigation demonstrations they observed. In groups, or together as a class, fill in the Irrigation Comparison Worksheet to evaluate the pros and cons of each of the main types of watering techniques. See possible responses on the next page.

3. After making your lists, ask students again to consider: Is there one best technique? (Make sure they understand that the answer is no, the irrigation system should be determined by the needs and conditions of each individual growing space). Do different techniques work better in some garden situations than others? What would be best for our school or your home garden?

4. Conclude by reviewing lessons from the previous Modules and why it is important for us to conserve water and protect our water resources. Discuss how irrigation technology plays an important role in these efforts.

Possible responses for the Irrigation Comparison Worksheet

Irrigation Method	Benefits	Challenges	Example Garden Situation to Use
Hand Watering	• Inexpensive • Allows for targeted water delivery • Allows you to monitor soil conditions as you water	• Time consuming • Labor intensive	• Small container garden • A garden bed where only a few plants need extra water regularly
Sprinklers	• Can be inexpensive • Save time	• Can waste water if not monitored • Built-in systems can be costly and complex to design/install	• Large garden area with lots of plants needing frequent water • Large garden bed where all plants need the same amount of water
Drip Irrigation (soaker hoses, emitter hoses, and olla pots)	• Efficient water delivery • Save time	• May not be as targeted as hand watering • More expensive initially than hand watering and many sprinklers	• Small-to-medium-sized in-ground beds and raised beds • Garden areas where plants may need different amounts of water

Irrigation Comparison Worksheet

Irrigation Method	Observations	Benefits	Challenges	Example Garden Situation to Use
Hand Watering				
Sprinklers				
Drip Irrigation: (soaker hoses, emitter hoses, and olla pots)				

1. Which of these irrigation methods do you think would be best for our garden? Why?

2. What additional information would be helpful for you to gather to be able to carefully evaluate these irrigation systems?

Activity 3: Irrigation Systems

Learning Objective:

Students will compile information needed to aid in selection of an irrigation system.

Background Information:

In order to provide supplemental irrigation to a garden or landscape and to determine which type of system would be best, gardeners need a solid understanding of site conditions and water sources. It's helpful to gather some information in the planning process, such as determining the composition and water infiltration rate of the soil and investigating the site's water source, including water pressure and flow rate.

Evaluate Your Soil

Water provided by rainfall or irrigation is only useful for plants if it is probably absorbed and stored by the soil. Healthy soil works like a sponge, soaking up water and allowing it to be processed slowly into the environment. Some of this water stays in the topsoil to support plant life. Some slowly percolates down through the layers of the soil to recharge groundwater sources such as aquifers.

Soil composition impacts how water is absorbed. Clay soils are slow to absorb water, but they tend to hold moisture longer and can become oversaturated. Sandy soils drain quickly, so they dry out faster. Loam soils have a combination of sand, silt and clay particles and are generally the optimum mixture for garden soil. The soil ribbon and soil mudshake tests are two ways to get an approximate calculation of soil texture.

Understanding soil composition can help you make choices about soil preparation and irrigation. Sandy or clay soil can be improved by adding compost. Organic matter like compost improves water infiltration in clay soils and boosts water-holding capacity in sandy soils. In terms of irrigation, sandy soils will need to be watered more often than clay soils, and gardeners need to be extra careful not to overwater clay soils. Both sandy and clay-leaning soils can benefit from slower water application.

There are a number of ways to explore how well water moves through the soil including observation and by using an infiltrometer.

Evaluate Your Water Source

A first step is to confirm you have a water source close to your garden. If you plan to grow edible crops, make sure it is a potable water (safe for human consumption). Additionally:

Check Connection. Most irrigation systems will be connected to an outdoor spigot with a standard, threaded connection. Make sure that the spigot has a backflow preventer already installed. It's common for most water sources to have a backflow prevention device added at installation.

Measure Water Pressure. If you're getting your water from a municipal source or drilled well, there will likely be adequate water pressure for all but the largest garden plantings. Water pressure is the force of the flow and is measured in pounds per square inch (PSI). Both municipal water sources and drilled wells generally deliver water at a pressure of 40 to 80 PSI. Drip systems require a pressure between 10 and 30 PSI and, therefore, require a pressure regulator to reduce the pressure. Water pressure can be measured using an inexpensive water pressure gauge available at hardware stores.

Measure Flow Rate. The flow rate also helps definite the amount of water available for your irrigation system and can help you determine how large an area you'll be able to water. Flow rate is a measure of the quantity of water that flows over a given time period and is measured in gallons per minute (GPM) and gallons per hour (GPH).

A simple way to determine flow rate is to place a 5-gallon pail beneath your water source, open the valve completely, and count how many seconds it takes to fill the pail.

If it takes 30 seconds to fill the 5-gallon pail, your flow rate is 10 GPM. Here's the math:

30 seconds = 0.5 minutes; 5 gallons divided by 0.5 minutes = 10 GPM; 10 GPM x 60 minutes/hour = 600 GPH

Most municipal water systems have an adequate flow rate for drip irrigation in a small-to-medium youth garden, so it's not necessary to know the flow rate. However, for some drip irrigation systems, knowing the flow rate (along with your soil type) helps you determine the type of drip tubing or emitter you'll need and the number of zones you may need to divide your garden into for watering.

Resources:

Soil Texture and Composition. KidsGardening. https://kidsgardening.org/resources/lesson-plans-soil-texture-and-composition/

Educators' Guide to Drip Irrigation. KidsGardening. https://kidsgardening.org/the-latest-waterwise-garden-program/

Rain and Soil Lesson. Soil Science Society of America: https://www.soils4teachers.org/files/s4t/lessons/rain-and-soil-lesson-earthscienceweek17.pdf

Materials:

- soil samples
- water
- a clear, plastic container
- a ruler
- shovel

- empty large coffee can with both ends removed
- permanent marker
- water measurement tool (graduated cylinder, measuring cups, 2-liter bottle or gallon plastic container)
- timer
- 5-gallon bucket
- Water pressure gauge
- Soil Evaluation Worksheet
- Water Source Evaluation Worksheet

Instructions:

1. Explain to students that you are going to explore some factors that may impact your garden and irrigation planning. These include evaluating the soil and investigating your water source.

2. Use the Soil Evaluation Worksheet to record your results from the following tests:

Ribbon Test

The ribbon test can be used to estimate the amount of sand, silt and clay in your soil:

- First, take a small clump of soil and add water until it makes a moist ball.
- Rub the soil together between your fingers. If the soil makes a nice, long ribbon, then it has a lot of clay in it (thus sticks together well). If it crumbles in your hand, then it has a lot of sand. If it is somewhere in between, then you probably have a good mix (a soil with a good mix of all 3 components is called a loam).
- Ask students to estimate what percentage of each component they think is present. Explain that the ribbon test may not be exact, but scientist may use it in the field to create a general description of a soil since it is very easy to implement (all you need is a little water).

Mudshake Test

"Mudshakes" provide a more precise way to observe soil composition. To create a “mudshake:”

- For each soil sample, have students fill a clear container about two-thirds full of water; then add enough soil to nearly fill the jar. You can also add a pinch of laundry detergent to help the soil components separate well.
- Shake the jar vigorously; then observe the jar over the next couple of days as the particles settle into layers. The larger particles, sand, are heaviest and will settle at the bottom, followed by silt, with the last full layer being clay. The clay may stay suspended and cloud the water for a long time. Organic matter will float on or just below the water surface.
- Once the jar has settled, compare the results to your ribbon test. Measure the height of each layer and then translate that into percentages for each component (height of each component divided by height of the sample). How accurate were your estimations from the ribbon test?

Drainage Test

For a general measure of soil drainage:

- Dig a hole 6 inches wide and 18 inches deep in each location you want to test.
- Fill each hole with water and measure depth with a ruler.

- Check on water depth every hour and record results.
- If all the water drains within a few hours, the site has excellent drainage. If the water drains within 24 hours, then it has moderate drainage, but could benefit from some amendments. If the water has not drained in 48 to 72 hours, then you should choose a different location.

Infiltration Test:
To calculate a more precise infiltration rate you can use an infiltration ring. Although these can be purchased, the Soil Science Society of America provides detailed direction for a DIY version.
- Create an infiltration ring by cutting the bottom off of a large metal coffee can
- Use a permanent marker to make measurement lines inside the can. One line should be 1/3 of the way from the bottom and the second should be 1/3 of the way from the top.
- Sink your infiltration ring to the bottom 1/3 mark into the land you want to test.
- Next, create a way to pour measured amounts of water into the can. You can use a graduated cylinder, a measuring cup or create your own measurement tool by adding marks along the side of a 2-liter bottle or gallon plastic milk jug.
- Set a timer to 2 minutes. Fill the can to the top measurement mark and keep filling it to that mark over the 2 minutes. At the end of the time, record how much total water was added over the time.
- Compute the depth of the water divided by the elapsed time to find an infiltration rate. To find the depth of the water, you will need to first find the surface area of the infiltrometer ring. Then divide the volume water added by the area of the ring. See the Soil Evaluation Worksheet for help with the calculations. Additional instructions are also available in Rain and Soil by the Soil Science Society of America.

3. Once tests are completed, discuss your findings as a group and how these might influence soil preparation and irrigation planning.

4. Next investigate your water source using the Water Source Evaluation Worksheet which includes:
   - Does your water source have potable water?
   - Does the spigot have a backflow preventor? (Ask for help from your maintenance staff if you are not sure.)
   - Measure water pressure
   - Measure water flow

5. Conclude experiments by discussing how these findings can be used to help with garden planning and irrigation design. Would amending our soil be beneficial for using water more efficiently? What will be the water source of our new or expanded garden space? Is our water source sufficient for our needs?

Extend the Learning:

The Educator's Guide to Drip Irrigation provide detailed directions for planning a drip irrigation system for a raised bed garden. If applicable to your school garden plans, students can use this publication to design a drip irrigation system.

Soil Evaluation Worksheet

Ribbon Test Results:

Soil texture feels: clayey sandy loamy

Mudshake Results:

___ % sand
___ % silt
___ % clay
___ % organic matter

Drainage Dig:

How long did it take for the water to completely drain from the 18” hole:

Infiltration Experiment:

How much water was added to the can over the 2 minutes (measured in mL):

Infiltration Rate:

= depth of water added/elapsed time

To find depth of water:

Surface Area of the Infiltrometer (r= radius of the ring/can; measure in cm):

$A = \pi r^2$

Depth of water

Volume of water added/Surface Area (A):

1. Based on these test results, provide a prediction of how well our soil will absorb and retain water.

2. Would you recommend making changes to the soil?

3. How does this information influence our irrigation planning?

Soil Evaluation Worksheet

1. Does the water source for the garden have potable water (safe to drink)?

2. Does our spigot have a backflow preventer?

3. Water Pressure (PSI):

4. Water Flow Rate:
   How long did it take to fill our 5-gallon bucket?

   Calculate the flow rate:
   = 5 gallons/# of minutes to fill the bucket

5. Based on these findings, do we have a good source of water for our garden?

6. What kind of irrigation tools should we consider using?

Module 5 Next Generational Science Standards

The following standards inspired the activities in the Waterwise Garden Stewards Unit:

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

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.

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.