

GARDEN LESSON PLAN: WATER

Many elements are interconnected and function together to create the natural and productive living system that is your garden. Look to the end of this activity guide for additional lesson plans, activity guides, and videos that can help you bring together soil, water, habitat, food, and community to explore your dynamic garden ecosystem.

Subject Area: Gardens, General Science

Grade Levels: Geared toward 6th-8th grade, but can be tailored for all grades

Essential Question:

How does a garden model a healthy watershed?

Purpose and Overview:

The purpose of this activity guide is to help students understand their garden as a model watershed through the collection and analysis of rainwater filtration data. This guide serves as an extension to *How Natural Areas Filter Water* lesson plan.

In this guide, students explore the relationship between rain filtration in a garden and water quality throughout the surrounding watershed. Students calculate the permeable surface area of the garden and periodically measure rainfall amounts at the garden, then use these data to determine how much rainwater their garden has filtered.

Time:

This lesson is part of an extended learning experience that engages students in creating and maintaining a school garden. The following are suggested time allotments for each section of the guide.

- **Engage:** one 45-minute class period
- **Explore:** two 45-minute class periods
- **Explain:** one to two 45-minute class periods after students have collected rainfall data for several weeks
- **Evaluate:** one 45-minute class period
- **Extend:** Allow one to two 45-minute sessions for follow-up activities selected from this section.



Materials and Resources:

Materials for teacher

- Computer with Internet connection
- Rain gauge (optional)
- Garden or other natural area that filters water on your school campus

Materials for each student or group of students

- Garden notebook
- Computer with Internet connection
- Tape measure or other form of measurement
- Calculator
- Handouts listed below
 - a. Rain Filtration Field Report
 - b. Water Filtration Evaluation

Videos supporting this activity guide

- Make Clean Water (<https://vimeo.com/77811268>)
- Global Gardens (<https://vimeo.com/77792707>)
- YouTube video showing a simple experiment of impervious versus natural surfaces: <https://www.youtube.com/watch?v=Dw9p8jEB7m0> (note that this is a replicable activity with directions in the *How Natural Areas Filter Water* lesson plan)

Gardens How-to Video Series:

- Planning Your Garden (<https://vimeo.com/91446626>)
- Building a Garden in a Day (<https://vimeo.com/91445078>)
- Caring for Your Garden (<https://vimeo.com/92520693>)
- Fears in the Garden (<https://vimeo.com/92531513>)

Objectives:

Knowledge

- Measure the permeable surface area of the garden.

Comprehension

- Record and interpret rainfall amounts by collecting data directly (e.g., with a rain gauge) and/or from a reliable source (e.g., weather reporting website).
- Describe the ecological services provided by a watershed.

Application

- Distinguish between permeable and impermeable surfaces.
- Use data collected to estimate rain filtration over periods of time.

Analysis

- Describe the impact of permeable and impermeable surfaces on the natural process of rain filtration and water quality.

- Solve quantifiable problems related to the rain filtration capacity of permeable surfaces within the school garden.

Synthesis

- Formulate an evidence-based opinion on the cumulative effect of rain filtration provided by gardens and other green areas in the region.
- Construct an argument to show the key role rain filtration plays in regional watersheds.

Evaluation

- Define concepts such as permeable, impermeable, filtration, run-off, and watershed.

Next Generation Science Standards:

Disciplinary Core Ideas:

- ESS2.C The Role of Water in Earth's Surface Processes
- ESS3.A Natural Resources
- ESS3.C Human Impacts on Earth Systems

Crosscutting Concepts:

- Patterns
- Cause and Effect
- Stability and Change
- Influence of Engineering, Technology, and Science on Society and the Natural World

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

Performance Expectations:

Middle School

Activities in this lesson can help support achievement of these Performance Expectations:

- LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- 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.
- ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geo-science processes.
- ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Common Core Standards:

6th-8th Grade Science and Technical Subjects

- CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks.
- CCSS.ELA-Literacy.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.
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- CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g. in a flowchart, diagram, model, graph, or table).
- CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Vocabulary:

Filtration: The process that occurs when water passes through soil and flows underground.

Impermeable: Unable to pass through, as it relates to a surface or material.

Permeable: Allowing fluid to pass through, as it relates to a surface or material.

Pollution: Unwanted chemicals that impact water quality.

Run-off: Water that drains across surfaces into streams and rivers following rainfall.

Watershed: An area of land where all of the water that is under it, or drains off of it, flows to the same river, basin or sea.

Background:

In this lesson, students will observe and record rainfall to determine how much rainwater is filtered by their garden. The goal is to help students understand that the ecological benefits of the garden include improved water quality for the surrounding watershed. They will learn that the permeable surfaces that are part of the garden ecosystem naturally absorb and filter rainwater that otherwise could collect pollutants on impermeable surfaces, flow into the sewer system, and continue into natural waterways, where it could cause harm to all members of the ecosystem.

Engage

Please refer to the *How Natural Areas Filter Water* lesson plan for a full set of activities and suggested learning topics to engage your students around the topic of water.

1. Ask students whether and where they have seen a water filter. They might mention drinking water filters that fit on a faucet or sit in a pitcher and/or water filters used in aquariums and pools. Have students explain how a water filter works — it strains water through a porous material that removes impurities.

2. Ask students how their garden might work as a water filter. Remind them of what they have learned about the water cycle — how precipitation that falls on the Earth feeds rivers and streams and flows into the ocean. What part could their garden play in this process? (For a quick review of the water cycle, visit <https://water.usgs.gov/edu/watercycle.html>.)
3. Conclude this discussion by viewing the [Nature Works – To Make Clean Water](http://vimeo.com/77811268) video (http://vimeo.com/77811268 - 4 minutes).
4. Have students use what they have learned from the video to explain how a garden works as a water filter.
 - What is the porous material that removes impurities from the water? (soil, including organic material and organisms in the soil. You can use the YouTube video to see a demonstration of this at <https://www.youtube.com/watch?v=Dw9p8jEB7m0> or you can follow the guidelines in the [How Natural Areas Filter Water](#) lesson plan to do this as an activity with your class.)
 - Where does the filtered water go? (it sinks through the soil and flows underground to streams and rivers)

Relate this process to the concept that a garden acts as a “mini-watershed” (as described in the video at 2:40) by helping to filter and slow the movement of water.

5. Ask students how their garden works as a watershed and remind students of the part of the video where Bob Allen, Director of Conservation Programs at The Nature Conservancy in New Jersey, talks about how “lots of little things...add up to a big effect” (3:30-50 in the video). How does this apply to their garden? What about their community and other gardens in the area? What about gardens across the country?

Explore

Collecting Your Data in the Garden

Once you have engaged the students in discussion around how water works in natural areas and in your garden, you are ready to begin collecting data on the conservation impact of your garden space. In this instance, you will lead your students through collecting data on how much rainwater your garden filters.

You may collect and track this data in 2 ways: either by building and using a rain gauge to track how much rainfall your garden receives and then using that data to calculate how much water your garden filters based on the permeable surface area of your garden; or, you may use average rainfall data for your area, accessible online, to calculate rainwater filtration in your garden. See below for resources and instructions on how to collect data in these ways.

1. Distribute copies of the *Rain Filtration Field Report* handout for students to keep in their garden notebooks. Explain how students will use this sheet in the garden to record their measurements of rainfall. Alternatively, tablets and other mobile devices can be used in the garden to record your data directly into the data collection system if these tools are available to you.

2. Discuss how often the class will record rainfall amounts — Only after it rains? Every day at a specific time? Every week at a specific time? What are the advantages and limitations of each approach? Guide students toward the conclusion that a more systematic approach will yield more scientifically accurate data.
3. Evaluate with your students the two approaches: measuring rainfall with a rain gauge vs. taking measurements from a weather website. Which method is better? What are the pros and cons of each method?

How to Make a Rain Gauge

A rain gauge is simply a container that collects rainfall with a ruler positioned to show the depth of the water collected. There are many different ways to make a basic rain gauge. You can choose any of the methods described on the web sites listed below, or have students work in small groups to make several types of rain gauges, including other types that they research online.

- National Weather Service: web.archive.org/web/20140306134927/http://www.crh.noaa.gov/abr/?n=rain_gauge.php
- Education.com: www.education.com/science-fair/article/DIY-rain-gauge/
- Scholastic: www.scholastic.com/parents/resources/free-printable/science-printables/make-rain-gauge
- Instructables: www.instructables.com/id/Make-a-Rain-Gauge/ (a math-intensive approach)
- Woodland Park Zoo: blog.zoo.org/2012/06/rain-or-shine.html

If time permits, you might also want to introduce students to some more advanced types of rain gauges:

- 8-Inch Standard Rain Gauge used by the National Weather Service: web.archive.org/web/20150203145210/www.crh.noaa.gov/iwx/program_areas/coop/8inch.php
- Tipping Bucket Rain Gauge: web.archive.org/web/20150403055243/http://weather.about.com/od/weather_faq/a/RainGauges.htm (includes an animation that shows this rain gauge in action)
- Optical Rain Gauge: www.rainsensors.com

Students can make the measurements on their rain gauge as precise as they like; just make sure that they are recording data in a consistent manner. For example, if they make a rain gauge to measure rainfall in 0.01-inch increments, make sure they always record and report data in 0.01-inch increments to ensure consistency over time.

Have students place the rain gauge in an area of the garden where there are no overhead obstructions. When it is time to collect rainfall data, appoint a pair of student “rain monitors” to read the gauge and report their findings back to the class, so that everyone can record the information onto the Field Report.

If your students make several rain gauges, have them position them around the garden and compare the data provided by each one. Students will likely discover that every gauge gives a slightly different measurement of rainfall. Challenge students to explain how the design of each rain gauge, its placement, and even the observational skills of those reading the measurements might account for these differences.

Explain

Resources to calculate filtration using rainfall data

If students do not use a rain gauge, they can obtain rainfall data for their garden from a weather website that provides records of past weather activity, such as rainfall, in addition to the usual forecasts. For example:

- At <https://www.weather.gov>, enter the zip code for your garden in the search box at the upper left corner of the homepage and click “Go.” This displays a page showing current weather conditions for the area covered by the zip code. Click the “3 Day History” link to the right of this information for a table showing hourly weather observations within this area over the past 72 hours, including hourly measurements (in inches) of precipitation for the prior hour, 3 hours, and 6 hours which you can use to calculate the amount of rainfall for a specific period.
- At <https://water.weather.gov/precip>, zoom in on the part of the map that shows your state, then use the buttons below the map to select a time period from the archive, either a single day or a single month. The map will display the pattern of precipitation for that time period using a color code to indicate the amount of precipitation (in inches or millimeters).

Note that gathering data from a weather website can require keeping to a strict schedule. Students would need to check weather.com, for example, every day or every seventh day — if they skipped a day or checked on the eighth day, the data would no longer be available. Only the precipitation map at <https://water.weather.gov/precip> allows you to retrieve data for any specific time period.

Choose a weather website for your students, or allow students to explore the sites listed above (as well as other sites they might discover) and choose the one they will use for their rainfall measurements. When it is time to record the data, visit your selected website as a class so that everyone can enter the information onto the Field Report. Remember, for consistency, it is important to always obtain data from the same website.

Evaluating, Entering, and Tracking Your Data

Help students self-evaluate their data before you enter it into the data collection tool. How scientific was your process for collecting data? How are you collecting data so that it is consistent and accurate? What changes might you make if you were to collect data over another time period?

Optional: Have students write in a garden journal about how they have collected data, why and how this process is a scientific one, and what they can do to improve their process and results.

1. Calculate Water Filtration¹

Before entering your data into the system, have students use the following formulas to calculate how much water their garden is filtering based on the permeable surface area of the garden.

The multiplier for water filtration below is based off this equivalency:

1 foot x 1 foot x 1 inch = 0.623 gallons or 2.36 liters

y = permeable surface area in square feet (ft²)

z = rainfall amount in inches

For gallons:

For liters:

For example, if the rain gauge says it has rained 3 inches this week and I want to calculate the gallons of water filtered from my 100 square foot garden space, the calculation would look like this:

$$100 \text{ ft}^2 \times \left(3 \text{ inches} \times \frac{0.623 \text{ gallons}}{1 \text{ ft}^2 \times 1 \text{ inch}} \right) \\ = 186.9 \text{ approximate gallons of water filtered}$$

¹ These formulas are based on 1 square foot of permeable surface filtering 0.623 gallons or 2.36 liters of water per 1 inch of rainfall. These figures have been checked by Nature Conservancy scientists. Please note however that many factors will affect the amount of water that your garden filters including transpiration by plants, soil type and quality, grade of the land, depth of the soil, etc. Your resulting data will therefore not be 100% accurate but is designed to be used as a teaching tool.

Evaluate

Use the Water Filtration Evaluation student handout to evaluate what your students have learned. See the scoring key below.

Scoring Key for Evaluation

1. Describe an example of a permeable surface and an impermeable surface.
Specific answers will depend on your school garden's set-up. General answers might include:
Permeable surfaces — all surfaces that contain soil, garden beds, planters, pots, etc.
Impermeable surfaces — concrete or stone surfaces, metal structures, paved areas, etc.
Students should also describe what makes these surfaces permeable or impermeable.
2. Describe how permeable surfaces aid natural rain filtration.
Permeable surfaces allow water to be absorbed naturally into the soil. Their presence allows for better overall health of the regional watersheds because of the collective capacity for these natural areas to absorb water and keep it from collecting pollutants that filter into the watershed.
3. Describe how unfiltered rainwater can harm the environment.
Water that collects on impermeable surfaces is harmful to the environment because it can collect pollutants from construction sites, agricultural run-off of pesticides and fertilizers, oil and chemical spills, waste, etc. before eventually making its way into the water systems that make up a region's watershed.
4. Describe how you used technology as part of learning about filtration.
Answers may vary but should describe an individual student's use of online technology from any aspect of participating in this study unit.
5. Give an example of how people can help protect the watershed by improving rain filtration.
Answers may vary but can include: Conserve water, plant gardens, advocate for more green spaces, plant crops wisely by incorporating plants that require less watering, follow city or county guidelines for recycling waste properly, etc.

Extend – Further Investigations

Use these additional activities to extend the learning experience, work outdoors with your students, and further investigate your garden watershed.

Permeable and Impermeable Surfaces

1. Students can also observe the difference between permeable and impermeable surfaces with a simple outdoor demonstration. Choose a slope on your school campus where an impermeable surface, such as a walkway or parking lot, runs beside a permeable surface, such as an open, grassy area. Measure a distance of several meters or yards for each surface, then use buckets to pour several gallons of water from the top of the slope down each surface simultaneously. Have students time how long it takes for all the water to flow down each surface. They will see how an impermeable surface allows water to flow quickly

and unfiltered into the watershed, while a permeable surface of soil and vegetation not only slows the water flow but also absorbs and filters much of the water. In fact, all the water may be absorbed by the soil before it reaches the end of your measured distance.

2. Build on the demonstration in Extension 1 by having students measure all the permeable and impermeable surfaces on your school campus and then use their rainfall data to estimate how much rain water has been filtered at the school and how much has run off unfiltered into the watershed. Ask students to suggest ideas for increasing the amount of rainwater filtration at your school. For example, are there opportunities for channeling water that drains from the school roof into a rain garden like the one shown in this unit's introductory video? Are there places where planters could reduce the amount of impermeable surface on walkways and courtyards? Are there some impermeable surfaces that can be replaced with permeable materials? Working in teams, students might turn their ideas into formal proposals that use the data they have collected to document how much rainwater could have been filtered by changing the campus in small ways.
3. To broaden students' perspective, use Google Maps (www.google.com/maps) to investigate the impact of impermeable surfaces within your community. Enter your zip code into the search box in the upper left of the Google Maps homepage, then click the Earth box in the lower left corner for a satellite view that will clearly show your community's roadways, shopping centers, industrial parks, rooftops, and other impermeable surfaces. Students can work in teams to survey these surfaces, zooming in on different parts of the community and using the scale at the lower right edge of the browser window to determine their area. (Click the scale to switch from miles and feet to kilometers and meters.)

Have students estimate the amount of rainwater that runs off from these surfaces each year using the normal annual precipitation data available at the National Climate Data Center (www.ncdc.noaa.gov/cdo-web/datatools/normals — click the “Annual/Seasonal Normals” tab, select your state, and then select the weather observation station nearest to your community.) Again, encourage students to suggest ways your community might reduce this run-off — for example, by creating parks at strategic locations, by planting buffers around large impermeable surfaces and along drainage ditches, or even by planting gardens on flat rooftops.

4. Conclude your investigation of rain filtration by returning to the garden for an activity from the Environmental Protection Agency that examines the “Role of Plants in Water Filtration” (www3.epa.gov/safewater/kids/pdfs/activity_grades_4-8_plantsinwaterfiltration.pdf). Students mix water with different substances and pour it into six potted plants, each with a catch-cup positioned below the pot's drain hole, to observe how soil and plant roots, as well as organisms living within soil, filter out different types of impurities. Your students can experiment with additional substances to test how well their garden filters rainwater.

Watershed Exploration

1. Introduce students to the watershed their school garden is helping to protect by exploring one of these websites as a class:
 - At the EPA's Drinking Water Mapping Application to Protect Source Waters (<https://www.epa.gov/sourcewaterprotection/drinking-water-mapping-application-protect-source-waters-dwmaps>), students can explore a map of the world and learn the source of drinking water in many locations. See the User's Guide (<https://www.epa.gov/sourcewaterprotection/user-guide-drinking-water-mapping-application-protect-source-waters-dwmaps>) for helpful information on navigating the application.
 - Students can also use Google Maps to investigate the impact of impermeable surfaces on the open waterways in their area and can visit the "Principal Aquifers" page of the U.S. Geological Survey's *Groundwater Watch* website (<https://groundwaterwatch.usgs.gov/GWWPrinAqfr.asp>) for interactive maps that report on conditions at aquifers across the country.
 - At *Surf Your Watershed* (www.epa.gov/waterdata/surf-your-watershed), the Environmental Protection Agency provides comprehensive information on every watershed across the country. Enter your zip code in the search box at the upper right of the homepage for a map that shows the extent of your watershed and the principal waterways flowing through it and links to a variety of reports on the watershed's condition. Click the video tutorial on the homepage for a complete introduction to all the resources available at this website.
2. *Surf Your Watershed* is especially valuable for providing a link to "Citizen-based Groups at work in this watershed" for every watershed in the country. Click this link to learn about organizations in your area that you can contact to arrange for a guest speaker or field trip that will enrich your students' understanding of the importance of watersheds and what we can do to help protect them. Students can also look to these organizations for volunteer opportunities, such as helping at a planned waterway cleanup or participating in a public education campaign. Your class might also want to partner with one of these organizations on a public awareness campaign in which students create posters, flyers, and video PSAs (which can be posted on your school and the organization's website) that spotlight a specific way to help protect your watershed, such as limiting the use of herbicides, pesticides, lawn fertilizers, and other gardening/lawn care chemicals that can threaten the watershed's ecology.
3. Have students work in different groups to complete each of the following options for a Protecting our Watershed Project and plan a day for groups to make presentations on their project.
 - a. Students use Google Maps to compare the amount of developed land (highways, buildings, houses, city streets, etc.) and undeveloped land (forests, fields, marsh, etc.) in your community and formulate a ratio based on their own observations. For example, the group might estimate that there is 4 times as much undeveloped land as developed land in your community. Students then develop an opinion on how this estimated ratio might

affect your local watershed, and use online resources to investigate how your city, county, or state environmental planning agency or planning commission regulate development and support environmental protections. As a group, students formulate an argument that supports current measures or advocates for greater or lesser protections and make their case in a class presentation.

- b. Students identify potential local sources of pollutants that can flow into the watershed through run-off from impermeable surfaces. Some examples: construction sites, agricultural sites, backyards (a source of fertilizers and pesticides), pet and livestock waste, oil and chemical spills, runoff from car washes, dumps and landfills. Students then use online resources to research your city or county's Clean Water restrictions and determine what measures local government has in place to limit this risk to your watershed. As a group, students present their findings and their conclusions about the effectiveness of local Clean Water regulations in a class presentation.
- c. Students investigate how your community can mitigate run-off from impermeable surfaces that are part of land development. To begin, students choose a prominent development in your area, such as a large apartment complex or shopping mall. Members of the group then visit online resources (such as the Environmental Protection Agency's "Low Impact Development" page, <http://water.epa.gov/polwaste/green>) to research ways to mitigate the impact on the watershed that large developments can cause. Finally, the group formulates a plan for increasing rain filtration and reducing run-off at the site they have chosen — for example, by integrating rain gardens and vegetation buffers into the development's infrastructure — and advocate for their plan in a class presentation.

Water Quality

1. Have students research incidents where contaminated run-off resulted in devastating effects to a region's water source, such as the case in West Virginia in early 2014 where a chemical spill allowed toxic build-up that overwhelmed the region's watershed systems not only due to the nature of the spill, but also because the chemical facility was built upstream within the watershed framework.
2. Have students investigate online city or county storm management websites to find out more about the plans and systems their city or town has in place to help curb pollutant runoff into the watershed. Then have students debate if their community might encourage the planting of gardens, either by individuals in their homes, by communities through land set aside for community gardens, or by schools as a way of providing resources, etc.

Forest Connection

Add an extra dimension to your investigation of rain filtration by introducing students to the concept of a tree's "dripline." This is the outline of a tree's foliage on the ground around the tree, marking the zone where rainfall drips from the tree to the soil. Students might imagine it as the border around the area covered by a tree-size umbrella. Have students select a tree and place rain gauges at its dripline and both inside and outside the dripline to determine how effectively the tree's leaves direct rainwater to this zone, which for most trees outlines the part of its root system that absorbs the most water. For more information on driplines, students can visit www.gardengrapevine.com/DripLine.html.

Additional Resources and Further Reading:

- Students may link to the *Gardens as Living Systems Activity Guide* to create and map a layout for a rain garden designed specifically to help increase water percolation back into ground-water aquifers.
- Through both garden observation and the results of rain filtration, students may review the Garden Design together with observations of the campus itself from the *Gardens as Living Systems Activity Guide* to determine if rain barrels would be useful in catching water runoff. If so, students may research how to make one or raise funds to purchase one.
- Students may use the *How Dirt Works* and *Gardens Improve Soil Activity Guide* to consider how soil composition and particle size (sand, silt, clay) may affect rain filtration in any ecosystem.
- More about impervious surfaces in urban environments: <https://water.usgs.gov/edu/impervious.html>
- Ecosystem services links and activities: <http://sciencenetlinks.com/lessons/ecosystem-services-water-purification/>

Rain Filtration Field Report

Use the following chart to record your data on how much rain falls on your garden.

Class: _____

Measuring Tool: Website - name: _____

Rain Gauge - type: _____

Date	Amount of Rain	Measuring Period	Total to Date	Notes

Water Filtration Evaluation

Using the data the whole class has collected, answer the questions below.

1. Describe an example of a permeable surface and an impermeable surface.
2. Describe how permeable surfaces aid natural rain filtration.
3. Describe how unfiltered rainwater can harm the environment.
4. Describe how you used technology as part of learning about filtration.
5. Give an example of how people can help protect the watershed by improving rain filtration.