Rainwater Harvesting

Lesson 5: How much water can we collect?

INTRODUCTION

In this lesson, students will learn how to calculate how much rainwater can be collected by their rainwater harvesting system. They will use variables such as the area of the collection surface and rainfall amounts for their city as well as the runoff coefficient (the percentage of precipitation that runs off a surface) to determine the amount of water in gallons per year that their system can collect. Computational thinking using dimensional analysis, also known as the unit factor method, will be employed to convert area in square feet and rainfall in inches to a volume in gallons. Note: *these are standard units of measure in the rainwater harvesting field.*

Teaching Strategies

To design a successful rainwater harvesting system, students need to understand the concepts of supply versus demand. In an ideal system supply should be equal to demand. In this lesson, students begin to understand the supply side of rainwater harvesting which includes how much water they can collect from the roof, or other surfaces. In future lessons, they will work with the demand side, putting that water to work.

OBJECTIVES

- **BUILD THE SYSTEM:** Identify the types of data needed to mathematically determine how much water can be collected in a year.
- **RELATE** the amount of water of water collected monthly to the design of a potential storage system.

MATERIALS AND EQUIPMENT

- Excel Spreadsheet: Supply Worksheet with Formulas.xlsx - see details below*
- Worksheet: Supply worksheet.pdf
- Handout: Runoff Coefficients for Different Surfaces.pdf
- Tool for calculating landscape area: https://earth.google.com/web/
- Monthly rainfall data for Santa Fe can be found at https://www.usclimatedata.com/climate/santa-fe/new-mexico/united-states/usnm0292 *Note*: *This link may need to be copied directly into your browser*.

*Depending on your students' abilities and your learning priorities for this lesson, you may choose to use either the Excel spreadsheet entitled *Supply Worksheet with Formulas* which will calculate monthly rain collection totals automatically or use a worksheet handout that students will complete manually (*Supply Worksheet)*.

The Rainwater Harvesting Unit is adapted with permission from the Arizona Project WET, Rainwater Harvesting Aqua STEM Program.

LESSON SUMMARY

In this lesson, students use data and observations of their collection area and average monthly rainfall data to calculate how much water can be harvested from their collection area (a portion of the school roof, parking lot, or other paved/non-porous area) over the course of a year. Students learn about the relationships between how much water falls on a roof surface or other collection area versus how much runs off, called the runoff coefficient (R_c). They identify trends in rainfall availability by month and draw relationships between rainfall and the amount of rain they may be able to collect. They use computational thinking to build the equation for figuring out how much water they can collect.

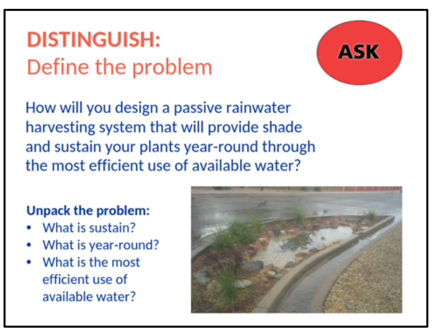
PRESENTATION GUIDE

Connect to the Unit

In the previous lesson, students constructed explanations for stormwater management and used the information to creatively design solutions to problems they discovered. Students determined the best locations of their school grounds to collect and/or direct water to a raingarden where it will infiltrate into the soil and irrigate plants.

Launch the lesson

This lesson will show students what runoff coefficients are, how to use them in determining the design of rainwater harvesting basins, and how to determine the amount of rainfall (supply) that can be collected over the course of a year for their chosen rainwater harvesting collection area.

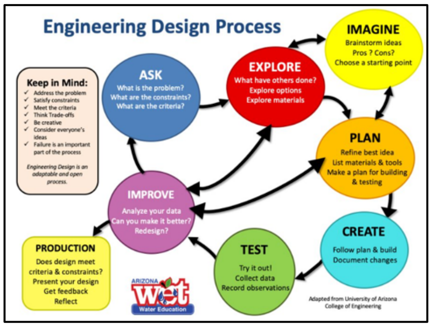


DISTINGUISH

- **What is the problem?**

Remind students of the problem they are trying to solve. *Design a rainwater harvesting system that will allow water to infiltrate into the groundwater system, provide shade at your school, and meet all the plants' watering requirements.* Remember to create an integrated design using the ***Principles of Rainwater Harvesting.***

- What plants provide shade?
- What are watering requirements?
    - Are watering requirements constant or do they change with seasons?
- What is meant by *integrated design*?
    - How does it affect plants that are chosen?
    - What functions does each part of my design serve?



Where are we in the engineering design process?

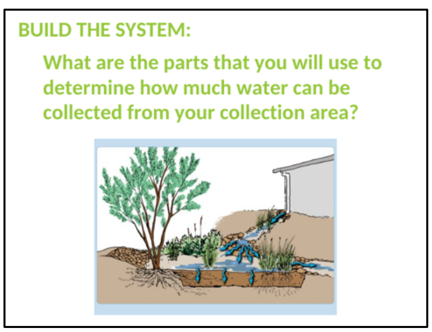
We are still asking, exploring and imagining.

DISTINGUISH:

- **What do you need to know to size your system appropriately?**

Ask the students what information they need to design and build a rainwater harvesting system that will meet the criteria and constraints.

One of the first things they need to know is how much water they can collect from their chosen collection area. They will also need to know how much water their plants need. In this lesson, students will focus on determining how much water can be collected and made available for their raingarden.



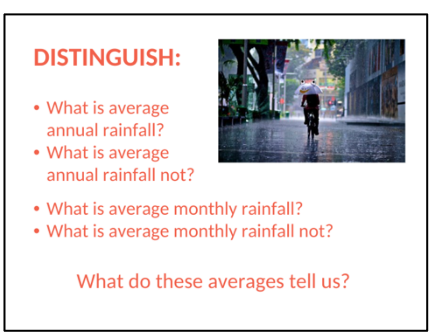
BUILD THE SYSTEM:

- **What are the parts that you will use to determine how much water can be collected from your collection area?**

Give students time in small groups to discuss this.

Students should understand that they need to know the how to calculate the surface area, in square feet, of their collection area. They will also need to know the amount of rain that falls on that surface in an average month. If they don't come up with these at this point, don't tell them. This is an opportunity to find out what they already know.

In this lesson, students will learn that the volume of rainwater they can collect will be dependent on the intensity of a precipitation event and will vary throughout the year. They will learn that the runoff coefficient also plays a role in how much rain they can collect.



DISTINGUISH:

- **What is average annual rainfall?**

The amount of rain that we usually get each year.

- **What is average annual rainfall not?**

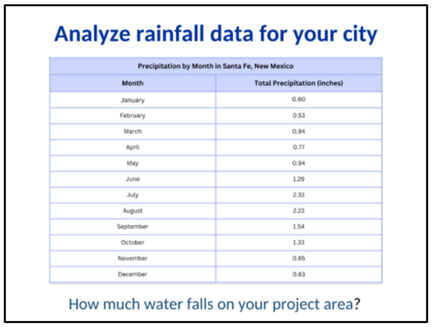
It's not monthly, weekly or daily data.

Ask students whether they think it would better to use daily, monthly, or annual rainfall values to determine the size of their system. What are the advantages and disadvantages of each?

- **What is average monthly rainfall?**

The amount of rain that we usually get in each month of the year.

- **What is average monthly rainfall not?**



Precipitation by Month in Santa Fe, New Mexico	
Month	**Total Precipitation (inches)**
January	0.60
February	0.53
March	0.94
April	0.77
May	0.94
June	1.29
July	2.33
August	2.23
September	1.54
October	1.33
November	0.85
December	0.83

It's still not daily. Would daily data be better to use than monthly? Why or why not?

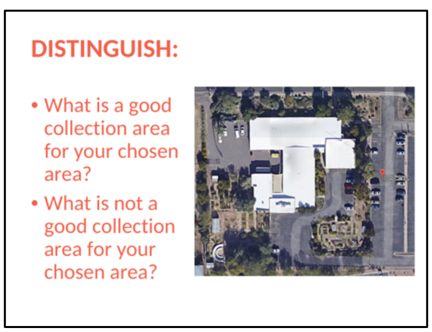
Discuss the frequency of precipitation in our area. Students will likely know about times of year when we get more rain, like the monsoon season. They may know that there are long periods with no rain too. Ask them: "Will annual or monthly data tell you about one big storm?" No, neither one will. "Would it be helpful to have more data on rainfall or less?" More, yet when is it too much and too time-consuming?

For most rainwater professionals using daily data is overkill. A constraint that we all have in designing and building a rainwater harvesting system is time. So, we are going to analyze monthly rainfall.

DISTINGUISH:

- **What else do you need to know to determine how much water could be harvested from your collection surface?**

We need to know the surface area of the collection surface that we will be harvesting from.



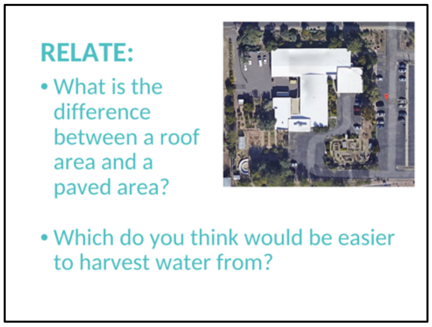
DISTINGUISH

- **What is a good collection area for your chosen area?**

The collection area for their system should have been determined in Question 8 on their Schoolyard Inspection Datasheet in Lesson 4. Ask students, "What constraints or criteria does a collection area need to meet?" (It must be close to the location to be watered, the rain garden basin. It must be an impermeable surface to collect water off, e.g., a roof or paved playground area.) Remember, where do we need shade?

- **What is not a good collection area for your chosen area?**

It is not any area off the school grounds. It's not a low point.



RELATE:

- **What is the difference between a roof area and a paved area?**

Engage students in a discussion of whether a roof area or paved/non-porous area on the ground would be easier to collect water from and why?

- **Which do you think would be easier to harvest water from?**

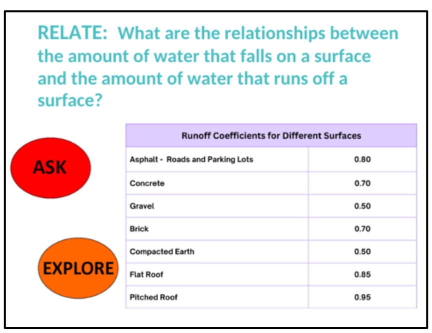
Higher areas might be easier to collect water from because you have the help of gravity, roof areas may already have structures you can use to help harvest rain (downspouts, gutters). Paved areas are lower and may require more work to direct water to useful locations, but this may depend on location. If you are capturing water off a parking lot, for example, you may need to make curb cuts that will then collect water from a much larger surface area than a roof.

How to calculate the surface area of the collection area:

Use the Google Earth link (https://earth.google.com/web/) to help your students find the area that they are planning on working with. Students may be working only with a portion of the roof or surface area for their projects. Circulate the room to ensure that students are using the formulas for various shapes to calculate their collection area. Note: *they may need to use different shapes and add the areas together.*

RELATE:

- **What are the relationships between the amount of water that falls on a surface and the amount of water that runs off a surface?**



Give student groups time to discuss and articulate the answers. Ideally, they'll know that the more impermeable a surface, the more water can be collected.

Why might different surfaces have different amounts of runoff?

Have students think back to Lesson 2 when they experimented with permeable and impermeable surfaces. Permeable surfaces allow rainwater to sink in. Impermeable surfaces shed rainwater. However, some impermeable surfaces shed more water than others.

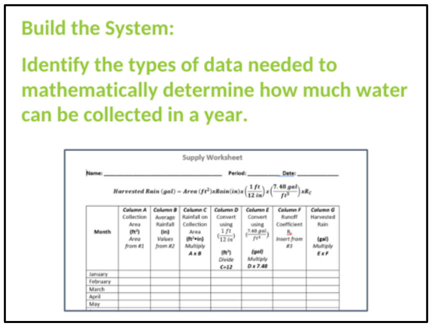
Would an asphalt parking lot shed more or less water than a gravel parking lot?

Show students a video explaining runoff coefficient, the amount of water that will run off a particular surface.

What is the runoff coefficient and what does it mean?

The runoff coefficient is the proportion of water that runs off a particular surface. It accounts for the loss of some water that is captured and stays on the surface rather than running off.

Have students study the chart of different runoff coefficients on different surfaces. Runoff coefficients for different surfaces can fall into a range of upper and lower bounds. For the purpose of this lesson, one number is given for each surface type.



BUILD THE SYSTEM:

- **Identify the types of data needed to mathematically determine how much water can be collected in a year.**

Introduce the *Supply Worksheet* to the students. Tell them the *Supply Worksheet* will help them think through all the factors that go into figuring out how much rain can be collected at their chosen location.

Some teachers prefer to pre-fill the worksheet with the appropriate rainfall data (see links to rainfall data above) rather than have students access and copy the data themselves.

The *Supply Worksheet* is also available as an Excel spreadsheet with formulas already inserted if you prefer students do this work on computers. (See the options for the Supply Worksheet at the beginning of this lesson.)

Supply Spreadsheet

To facilitate understanding, walk students through an explanation of each column on the spreadsheet. It may be helpful to use a document viewer to review the worksheet with students.

Column A – *Collection Area in ft^2*. This is calculated as below:

Area of Collection Surface: Length (ft) x Width (ft) = Area (ft2)

Column B – *Average Monthly Rainfall in inches* – you may opt to have them find the information themselves using the website links provided above or prefill the data on the worksheet before handing it out.

Column C – *Rainfall on Collection Area*. This is the amount of rain that falls onto the collection area. Students calculate this by multiplying Columns A x B.

Notice the units. ft^2•in. Is this a volume? Yes, but it is not a standard unit for measuring volume. What units do we use to measure volume? (ft^3, gallons, liters…) How do we get there? (We need to convert our units).

Column D is a *conversion factor* to get us to ft^3. How many inches in a foot? (12 inches)

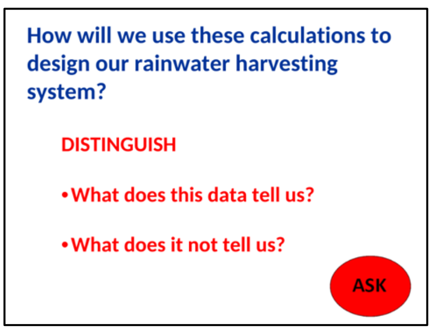
If we multiply our value by $(^{1\text{ft}}/_{12\text{in}})$ we can cancel out inches and Column D is the Rainfall on the Collection Area in ft^3. This process of converting values to a common unit is called dimensional analysis or the unit factor method.

Column E is another *conversion factor* to get us from cubic feet to gallons. How many gallons in a ft^3? $(^{7.48\text{gal}}/_{\text{ft3}})$ So, if we multiply by this conversion factor, it gives us Rainfall on Collection Area in gallons.

Column F of the *Supply Worksheet* is where students add the appropriate runoff coefficient for their collection surface. The runoff coefficient will not change for one type of collection area, so the same value is entered into every row. These are listed on the Runoff Coefficient chart. Note: *if they are using two different collection areas with a different runoff coefficient it would be better for them to use a second supply worksheet for the second type of collection area.*

Column G is how much water can be harvested from the collection area in gallons. In other words, it's the amount of water they can collect by month and over the course of the year.

Give them time to fill in the spreadsheet with the information they have. Circulate the room to make sure they are on task.



DISTINGUISH

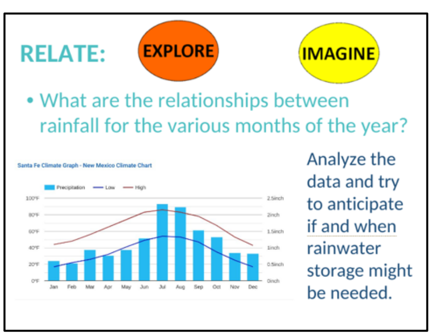
- **What does this data tell us?**

After they finish their spreadsheets, have them look at the amount of water which can be harvested per month versus the amount harvested per year. Compare the amount that can be harvested in each month. What does the data tell us?

- **What does it not tell us?**

It doesn't tell us about individual storm sizes.

The data only tells them the water they have available for use. It does not tell them if they have enough to meet their plants' watering requirements.



RELATE

- **What are the relationships between rainfall for the various months of the year?**
- **Which month will supply the most water? Which month will supply the least water?**

Have them refer to their supply worksheet to answer these questions. Have them think about how rainfall patterns may be a factor in designing a rainwater harvesting system that supports plants all year. They should notice that June through October has the highest amount of precipitation.

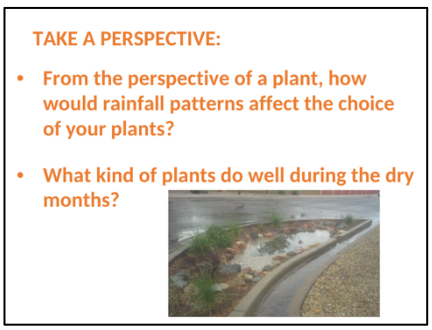
- **How might we need to accommodate months with low rainfall?**

They should understand that months with little to no rainfall will impact the types of shrubs and trees they can plant.

They should also consider what will happen to their rainwater harvesting system if an extreme weather event occurs and results in extensive flooding. More extreme storms are predicted for the southwestern U.S. in the coming years.

In designing our rainwater harvesting system then, we will also want to consider the impacts of a 100-year storm which drops several inches of rain in a matter of hours. Here in the Santa Fe area that means a storm dropping 2 inches or more of rain in 60 minutes.

The 100-year storm phenomenon then is an essential planning tool when sizing the storage part of their system. It should be added to the list of criteria. Note: *We'll look at how to incorporate this factor in student designs in Lesson 8.*



TAKE A PERSPECTIVE:

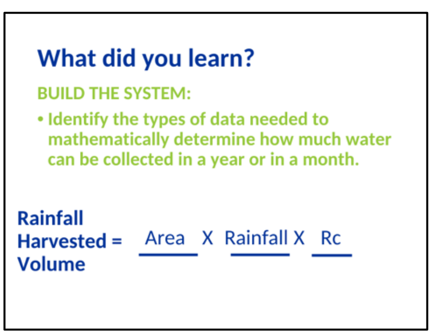
- **From the perspective of a plant, how would rainfall patterns affect the choice of your plants?**

Remember that the watering requirements for your plants need to be met by your system.

- **What kind of plants do well during the dry months?**

They should start to realize that native and or arid adapted plants should do through the dry months. Note: *This is just a quick preliminary discussion.*

CONCLUSION

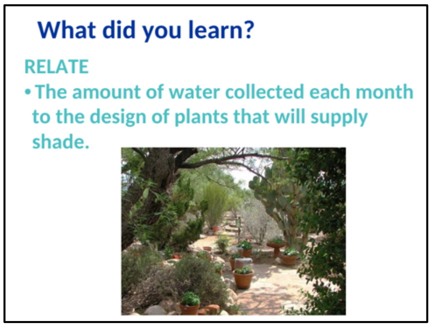


BUILD THE SYSTEM:

- **Identify the types of data needed to mathematically determine how much water can be collected in a year or in a month.**

Rainfall Harvested Volume = Area x Rainfall x Rc

(Rc is the Runoff Coefficient)



RELATE

- **The amount of water collected each month to the plants supported by that water to supply shade.**

Once students have completed the *Supply Worksheet* and applied DSRP thinking to analyze the data, return to your criteria and constraints lists. Which of the criteria and constraints questions does this exploration answer? Which criteria and constraints have been specified, clarified, or quantified by this exploration? What new criteria and constraints should be added to each list based on this exploration?