Rainwater Harvesting

Lesson 8: Basin Sizing

INTRODUCTION

In this lesson, students are reminded of the four major parts of a passive rainwater harvesting system: collection, conveyance, infiltration, and storage. In working through the unit, students have learned how much water they can collect from their collection area, and they know what plants they can grow with that water in order to meet the engineering design problem. Now they will have to figure out other parts of the puzzle. They will need to figure out a way for their plants to access the water and to plan and size their infiltration basins.

Students will be sizing their basins based on the 100-year storm or flood event for their region. They will use data on the percolation or infiltration rate to figure out the depths of their basins. They will have to iterate back and forth between depths and surface areas in order to store the amount of water needed for their plants. Iteration is a major part of the engineering design Process.

Teaching Strategies

This lesson utilizes research to analyze and interpret data about 100-year storm events and percolation rates. Students use mathematics and computational thinking to size infiltration basins to most optimally meet the engineering design challenge.

Students develop drawings of their basins using infiltration data and iterate back and forth using their data to optimize their storage capacity.

The NOAA website link enables students to find flood event data for their geographic area.

OBJECTIVES

- **BUILD THE SYSTEM:** Identify all of data needed to size basins to sustain plants year-round through the most efficient use of available water and meet city ordinances pertaining to standing water.
- **BUILD THE SYSTEM:** Use **mathematics and computational thinking** to size infiltration basins to optimally meet the engineering design challenge for the chosen site.
- **RELATE:** **Plan and carry out investigations** that relate water storage needs to water supply and demand.

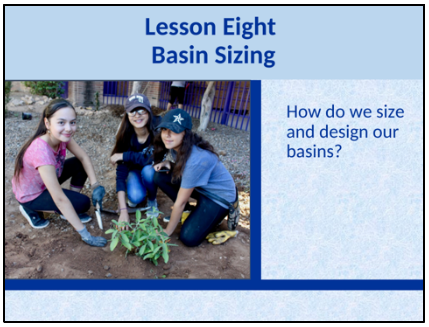
MATERIALS AND EQUIPMENT

- NOAA: https://hdsc.nws.noaa.gov/pfds/
- Brad Lancaster website: https://www.harvestingrainwater.com/resources/rain-garden-planting-zones/
- Water Budget Calculation Worksheet (filled out in Lesson 7)
- Santa Fe Basin Sizing Worksheet

LESSON SUMMARY

Students will learn to use data, mathematics and computational thinking to size infiltration basins to optimally meet the engineering design challenge. They will see that infiltration basins are a key part of their rainwater harvesting system, essential to meeting their plants' water requirements.

PRESENTATION GUIDE



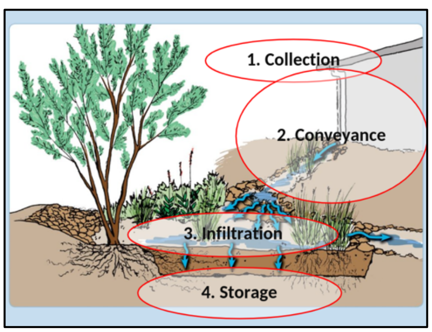
Connect to the Unit

In lessons 5 through 7, students learned to view rainwater harvesting from the perspective of supply and demand. They calculated the amount of rain that could be stored or used every month from their collection area and calculated the water demand needs of the plants for their project site. Now they will add another essential component to their system.

Launch the lesson

Students will be reminded of the four major parts of a passive rainwater harvesting system: collection, conveyance, infiltration and storage. They know how much water they can collect from their collection area and will now find a way for their plants to access the water. They will also need to plan and size their infiltration basins.

Students will be sizing their basins based on the 100-year storm or flood event for their region. They will use data on the percolation or infiltration rate to figure out the depths of their basins. They will have to iterate back and forth between depths and surface areas to calculate the amount of water storage needed for their plants.



Remind students of the driving question to be solved.

BUILD THE SYSTEM

• What are the parts of a rainwater harvesting system?

Ask students if they remember the four major parts or roles of a rainwater harvesting system that were discussed earlier in the unit. They should recall collection, conveyance, infiltration and storage.

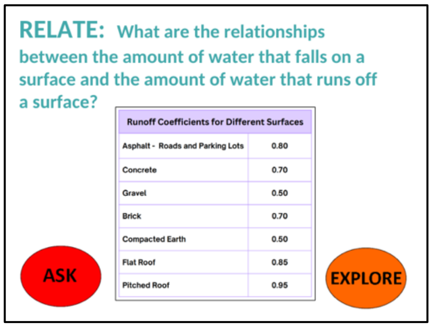
RELATE

• How are the parts related?

The following slides will assist in facilitating a discussion about how each of the components are connected to each other. Though covered previously, students should now have a deeper understanding of the relationships.

Collection: What are the Parts of Collection?

Collection includes type of surface, size of surface, and amount of rain.



RELATE

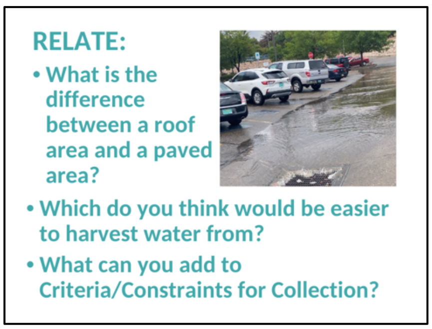
What are the relationships between the amount of water that falls on a surface and the amount of water that runs off a surface?

The key question is: *How much rainwater actually runs off a surface, like a roof?* Different surfaces produce different amounts of runoff.

- Permeable surfaces (like soil or gravel) allow water to soak in.
- Impermeable surfaces (like roofs or pavement) shed water, causing more runoff.

To calculate how much water will run off a surface, we use a **runoff coefficient (R_c)**. This number represents the proportion of rainwater that becomes runoff. It also accounts for some water loss—like water that stays on the surface or evaporates—instead of running off.

Remind students that the R_c varies based on surface type, and it's essential for estimating accurate runoff volumes.

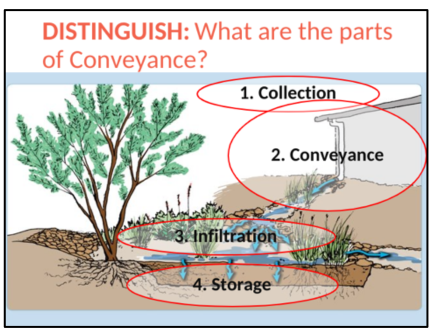


RELATE

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

One is higher and one is lower. Which do you think would be easier to harvest water from? In most cases the higher one because you can use gravity to help you move it into your system.

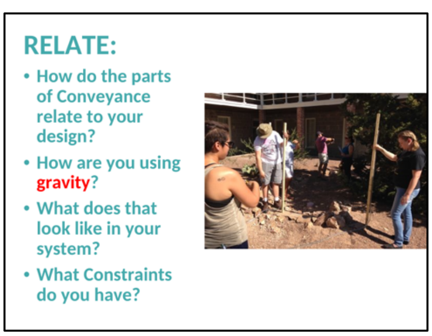
This ties into our Rainwater Harvesting Principles: Start at the top of the watershed and leads us into Conveyance.



DISTINGUISH

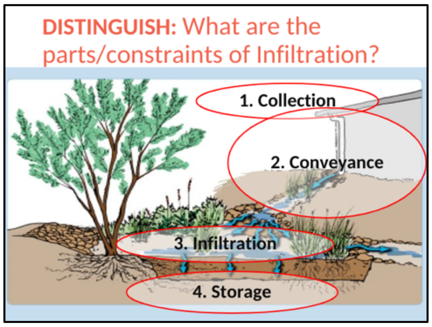
What are the Parts of Conveyance?

Elevation differences, gravity, infrastructure like rain gutters and downspouts.



RELATE

- How do the parts of Conveyance relate to your design?
- How are you using **gravity**?
- What does that look like in your system?
- What Constraints do you have?



DISTINGUISH

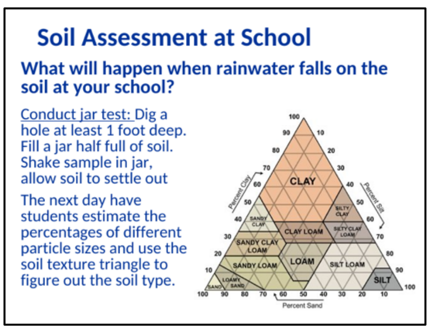
What are the parts and constraints of Infiltration?

Types of soil, percolation rate, mulch, and time.

We need to sink the water in a basin within 96 hours.

These are all Constraints for our design. We cannot change them.

Soil – Infiltration



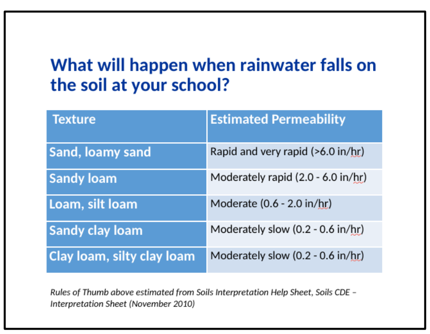
Ask, “Do you remember doing the Jar Test in Lesson 4?”

BUILD THE SYSTEM

- **What are the parts of the ground below the basin bottom?**

Soil types, compaction levels, and spaces between soil particles that allow water to pass through.

What is the percolation rate? How quickly water sinks or infiltrates into the ground at the site.



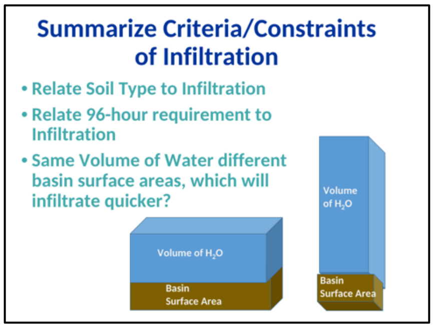
Soil Types and Permeability

As they discovered by performing the Lesson 4 jar test, sandier or more gravelly soils will allow water to infiltrate faster. Silt and clay inhibit the flow of water into the ground. Soil composition directly relates to how deep a basin should be constructed.

Basins – Potential Issue

What happens when water is left standing in a basin over time? Mosquitos breed. Mosquitos are vectors for several diseases which are currently on the rise due to climate change.

How does a city manage standing water? State water regulations tell us that all stormwater in a man-made basin must infiltrate into the ground in 96 hours – this is a criterion if it hasn't already been listed.



Summarize Criteria/Constraints of Infiltration

- Relate Soil Type to Infiltration

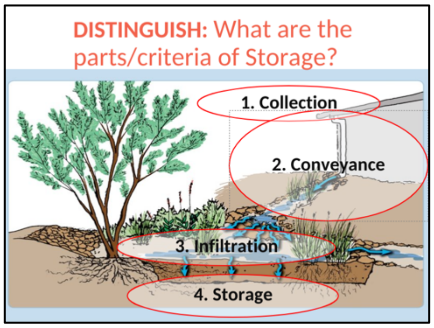
  Soil type will determine the infiltration rate of the water.

- Relate the 96-hour requirement to Infiltration

  Rainwater harvesting basins are considered retention basins. State water laws require that water infiltrates within 96 hours in a detention basin

- Given the same Volume of Water and different basin surface areas, which will infiltrate quicker?

  The time for a set volume of water to infiltrate will decrease if spread over a wider basin area.



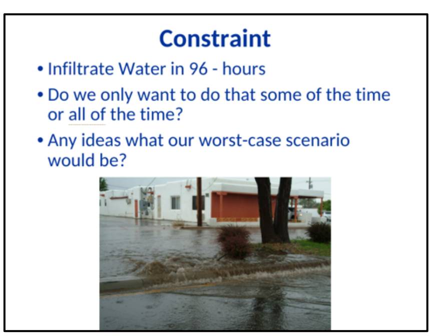
DISTINGUISH

What are the parts/criteria of Storage?

Plants store water—an amount that we determined in Lessons 6-7.

Selecting particular types of plants can also help with infiltration rates. This is in our Principals of Rainwater Harvesting document under Stacking Functions.

Area and Volume of Basins are also part of the storage.



Constraint

We are required to infiltrate water within 96 hours by state water law. This does not mean that we can selectively agree to obey the law.

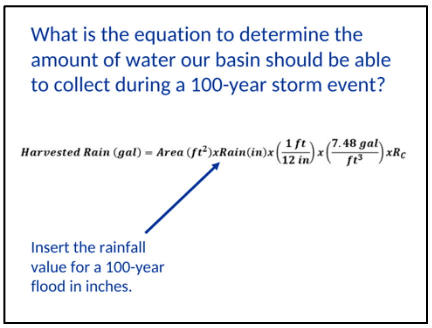
We also want to plan for our worst-case scenario of a 100-year flood event.

100-Year Storm Event

NOAA provides data on rainfall amounts for major storm events: https://hdsc.nws.noaa.gov/pfds/. These events are defined by how likely they are to occur in a given year.

A **100-year storm event** has a **1% chance of occurring in any given year**. Ask students: "Does this mean a 100-year storm only happens once every 100 years?" No—it could happen more than once in a year or in back-to-back years, depending on weather patterns.

As climate change progresses, extreme storms are becoming more frequent around the world.

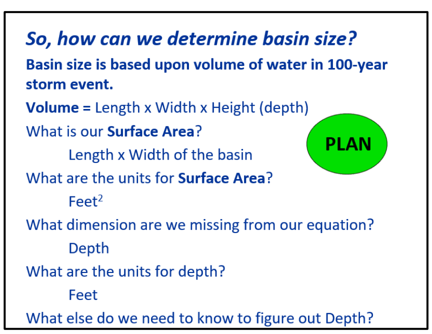


Ask**:** "If space isn't an issue, how much rain should we design our basin to hold?" Answer: The volume of rain from a 100-year storm event**.** Have students follow the directions on the slide to find this number—or walk through it as a class.

Ask again, "What volume of rain should we engineer our basins to handle if space is not an issue?" Answer: The volume of rain from a 100-year storm event. Have students follow the directions on the slide or do so through projection for the whole class.

In Santa Fe, we need to size our basin to handle a 2.0" rain event.

Review:
Again, how do we calculate that amount of water that comes off our collection area in a 100-year storm event? We use the same formulas we used in Lesson 5, except we plug in the rainfall for 100-year event to help us determine how big our basins need to be.



Basin Size

So, how can we determine basin size? Basin size is based upon Volume.

Volume = Length x Width x Height (Depth)

What information do we have?

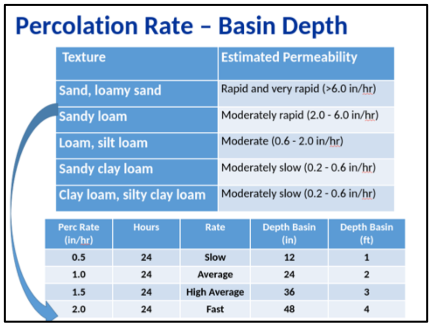
Surface area: Length x Width of the basin.

What are the units for surface area? (Square Feet)

What dimension are we missing from our equation? **Depth**

What are the units? (Feet)

Ask students: "What else should we consider when figuring out what depth our basins should be?" How hard is the ground? What depth would cause sides to be too steep? Are there safety considerations?



Examples of percolation rates with Basin Depth

This connects back to the infiltration or Perc test we did based on soil type. What is an infiltration rate? It's the rate at which water moves into the ground—measured in inches per hour.

This slide shows example infiltration rates. It helps us determine the maximum depth for our basin, based on how quickly the soil absorbs water.

Let's think through the numbers (use a yard stick or measuring tape to visualize).

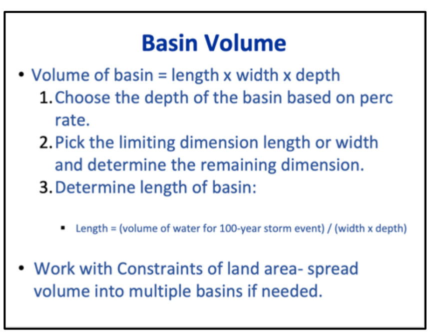
- Do we want a basin that's 4 feet deep on a school playground? No, that would be a safety risk.
- Is this a design constraint? Yes, we need to balance how fast water soaks in (perc rate) with safety and accessibility when planning basin depth.

How deep can we make this basin safely, given how the soil drains and how the space is used?

Remember from Lesson 4, we discussed Slope Safety:

Steeply sloped basins can be dangerous for people and pets. A good rule of thumb is to keep slopes at a 3:1 ratio or gentler—that means for every 3 units across (horizontal), the slope goes down 1 unit (vertical).

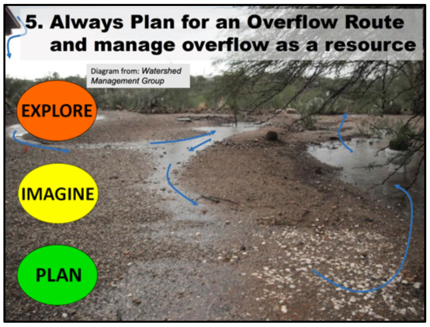
If your soil has Average or Slow infiltration rates, the basin should be shallower, which also means the slope should be even more gentle for safety and effectiveness. Remind students to think about both water movement and site safety when designing their basins.



Basin Design: This is an iterative process. Have students use the Santa Fe Basin Sizing Worksheet as they go through this process. Use grid paper and scale models to think about dimensions with students.

Volume of basin = Length x Width x Depth

- Choose the depth of the basin based on perc rate.
- Pick limiting dimension (Length or Width) and determine the remaining dimension.
- Determine Length (or Width if limiting) of basin:
  Length = (Vol water 100-year storm event) / (Width x Depth)
- Work within Constraints of land area. Distribute the volume into multiple basins as needed.



Plan for Overflow to Accommodate Excess Water

Take into account the actual area of land space and spread its volume into multiple basins as needed.

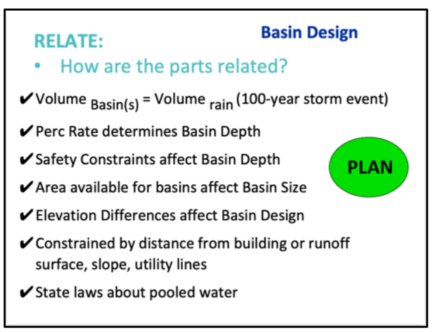
Give students time to figure out their basin configuration and dimensions. Make sure that they plan for overflow.

Optional: Have students think about plant placement when determining their basin depth. Check out Brad Lancaster's site: https://www.harvestingrainwater.com/resources/rain-garden-planting-zones/

At this point, students should understand that **effective rainwater harvesting systems are designed with large storms in mind**. Even if they can't store all of the water due to **space or safety limitations**, they still need to:

- **Calculate how much rain could fall** during a major storm.
- **Design safe overflow routes** to carry extra water away from buildings, walkways, and other important areas.
- **Place overflow outlets at a lower elevation** to prevent flooding or erosion.

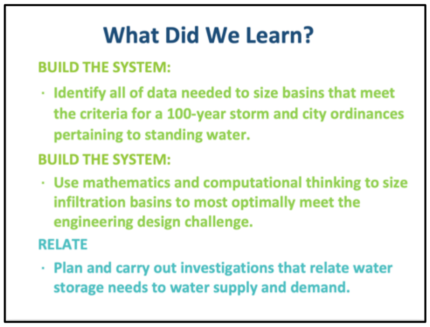
Reinforce that **concentrating water without planning for overflow** can cause damage—and the goal is to help the landscape, not harm it.



RELATE

How are the parts related?

- Volume Basin(s) = rain volume (100-year storm or flood event)
- Perc Rate determines Basin Depth
- Safety Constraints affect Basin Depth
- Area available for basins affect Basin Size
- Elevation Differences affect Basin Design
- Constrained by distance from building or runoff surface, slope, utility lines
- State laws about pooled water



Conclusions

BUILD THE SYSTEM

- **Identify all of data needed to size basins to sustain plants year-round through the most efficient use of available water and meet state laws pertaining to standing water.**

- **Use mathematics and computational thinking to size infiltration basins to most optimally meet the engineering design challenge for the chosen site.**

RELATE

- **Plan and carry out investigations that relate water storage needs to water supply and demand.**