Santa Fe WATERSHED ASSOCIATION

Rainwater Harvesting Unit Guide

INTRODUCTION

Using the Engineering Design Process, students will explore green stormwater infrastructure and design rainwater harvesting systems tailored to their own school campus. Their systems will aim to increase water infiltration into the soil, cool the surrounding area, and support native plant life. Taking a watershed-based approach, students will study the flow of water across their schoolyard to determine the most effective placement and design. Through this process, they will gain a clear understanding of how to build climate resilience in response to local threats such as rising temperatures, extreme storm events, and persistent drought.

OVERARCHING QUESTION

What's cool about rainwater harvesting in a warming world?

ANCHORING PHENOMENON

Climate change in New Mexico is leading to rising average temperatures, reduced snowfall, and more frequent extreme storm events during warmer months. These changes, combined with increased evaporation, are contributing to aridification across the region.

When precipitation falls, it moves through the watershed, flowing downhill as runoff. As it travels, water gains volume and momentum, especially over impermeable or semi-impermeable surfaces like pavement, eventually exiting the watershed through arroyos. However, when water is allowed to slow down and spread across permeable surfaces—such as soil and vegetation—it can infiltrate the ground. There, it supports plant life or percolates into the groundwater system, helping to retain water within the watershed and support local ecosystems.

OBJECTIVES

- Apply the Engineering Design Process to resolve an issue or solve a problem.
- Discover new technology and methods for saving water.
- Construct a model to represent your school watershed within the larger watershed.
- Use mathematics and computational thinking to support decision-making and planning.
- Relate rainwater use to overall water use and green stormwater infrastructure.
- Relate natural landscapes and the built environment to heat and flooding.
- Evaluate the design of a rainwater harvesting system that best meets measurable criteria and constraints.
- Communicate results and recommendations to peers and adults.

**Lessons are estimated to take one class period, except for Lesson 9 and Lesson 10, which are estimated to cover two class periods. Actual time may vary.*

LESSON 1:
HOW DO WE INCREASE OUTDOOR WATER CONSERVATION WHILE COOLING OUR COMMUNITY?

Concept: Climate models for the southwestern U.S. indicate a future of warmer temperatures, with higher localized temperatures for longer periods of time, less predictable precipitation, and increased aridity. Rain gardens are one example of green stormwater infrastructure that will conserve water and cool urban areas. They can also help us adapt to changing weather patterns, including less water in the form of snowpack and excessive heat.

Activate: By developing and using a model, students will differentiate between weather, climate, and climate change. They will analyze and interpret data related to climate change and the *urban heat island effect,* both of which are exacerbating heat in urban areas.

Check: Students will construct explanations and design solutions to mitigate the effects of extreme heat and aridification.

Products: *Weather Data Table – Santa Fe* worksheet and *Climate-Weather Student Questions.*

LESSON 2:
WHAT IS RAINWATER HARVESTING?

Concept: Passive rainwater harvesting functions as a system to collect, convey, store, and infiltrate water.

Activate: Students will design and explore the difference between permeable and impermeable surfaces using a physical model. They will use their model to learn about Best Management Practices (BMPs) for rainwater and stormwater. Finally, students will learn that water can be redirected for beneficial use by using a simple system; passive rainwater harvesting as a form of green stormwater infrastructure.

Check: Students construct explanations about how the parts of rainwater harvesting system are related to one another.

Product: *Storm Water Worksheet.*

LESSON THREE:
RAINWATER HARVESTING AND ENGINEERING DESIGN INTRODUCTION

Concept: The use of the Engineering Design Process (EDP) ensures that the very best rainwater harvesting system meets all criteria and constraints.

Activate: In this lesson, students will apply the first step of the Engineering Design Process (Ask*)* to their rainwater harvesting system design project. They will develop a list of criteria and constraints, and ensure that metrics are part of their problem statement.

Check: Students will define the problem that they are trying to solve and develop measurable criteria and constraints called for in the Engineering Design Process.

Product: Initial problem definition with Criteria and Constraints outlined. (Question #1 in *Your Rainwater Harvesting System Worksheet* from Lesson 9)

LESSON 4:
SCHOOLYARD SITE EXPLORATION

Concept: The flow of water follows patterns from high places to low places. By examining the school's watershed and using stacking functions, students can identify which locations offer the most benefits.

Activate: In this lesson, students will examine their school yard for physical evidence of where rainwater flows and evaluate rainwater management on campus. They will use their reconnaissance to locate the best place to harvest rainwater to grow trees and other plants.

Check: Students will construct an explanation for rainwater management at their school and identify potential problems they discover on their schoolyard site exploration.

Products: Map of schoolyard (using aerial view and/or graph paper) and the *Schoolyard Inspection Data Sheet*.

LESSON 5:
HOW MUCH WATER CAN WE COLLECT?

Concept: A passive rainwater harvesting system can be thought of as a supply and demand water distribution system. All the variables will need to be put together in order to calculate the amount of rainwater that can be expected to be harvested from a collection area monthly over the course of a year.

Activate: Students will learn how to calculate how much rainwater can be collected by their rainwater harvesting system using variables such as the area of the collection surface and monthly rainfall amounts for their city as well as a constant, the runoff coefficient, to determine the gallons per year their system can collect. They see trends in rainfall availability by month and draw relationships between rainfall and the amount of rain they may be able to collect.

Check: Students computational thinking and dimensional analysis to convert their units to gallons in the *Supply Worksheet* will be checked.

Product: *Supply Worksheet.*

LESSON 6:
HOW MUCH WATER DO WE NEED?

Concept: Different types of plants have different water needs. When designing a rainwater harvesting system, relating those needs to monthly water availability allows for the optimum capacity of a rainwater harvesting system.

Activate: Students will learn about the watering needs of various native and non-native plants and relate those needs to precipitation trends discovered in Lesson 5. They will perform an outdoor experiment (*Thirsty Plants*) to observe the important role plants play in the water cycle through transpiration. Students will identify the specific plants on their project site and research their water needs. They will also evaluate the use of native and non-native desert-adapted plants in their designs.

Check: Students will explain the differences between native and non-native plants for our region. They will identify the components of plant water demand and explain the relationships between the amount of water needed and the type, species, and size of plants.

Product: *Lesson 6 Proposed Plants Worksheet* and *Lesson 6 Proposed Plants Canopy Area*

LESSON 7:
CALCULATING PLANT WATER NEEDS

Concept: When designing a passive rainwater harvesting system, the water needs of each plant type must be calculated to determine if their water demand will be met. This ensures that the system is designed to maximize shade area while meeting watering requirements.

Activate: Using spreadsheets and reference material, students will calculate how much water they need to meet plant water demand in their project area and relate the plants' water needs to harvested water supply. They will analyze and interpret how selected plants will meet the engineering design criteria of providing shade and serving other functions in the integrated design of the rain basin.

Check: Students will use computational thinking and dimensional analysis to convert their units to gallons in the *Water Budget Calculation Worksheet*. They will also explain how their selected plants meet the engineering design criteria of providing shade and serving other functions in the integrated design of the rain basin.

Product: *Water Budget Calculation Worksheet_Santa Fe.*

LESSON 8:
SIZING BASINS

Concept: Sizing infiltration basins is done using data, mathematics, and computational thinking to optimally meet the engineering design challenge. Infiltration basins are a key part of the passive rainwater harvesting system, essential to meeting plants' water requirements.

Activate: Students will design their basins based on the projected runoff from a 100-year storm event specific to their region. Using data on soil percolation or infiltration rates, they will calculate appropriate basin depths. To ensure the basins can store enough water to support plant needs, students will iterate between adjusting depth and surface area—refining their designs to meet both volume requirements and site conditions.

Check: Students will identify all of data needed to size basins and use mathematics and computational thinking to optimize their designs and meet the engineering design challenge.

Products: *Santa Fe Basin Sizing Worksheet* and Basin Sketches.

LESSON 9:
SYSTEM DESIGN & IMPROVEMENT

Concept: <u>Two class periods</u> are needed to design, test, and revise rainwater harvesting systems. Data generated in the previous lessons will be integral to design systems. Learning to give and receive constructive peer feedback is an important part of the design process.

Activate: Students will compile their data using the *Your Rainwater Harvesting System Worksheet*. They will also need their Site Maps (to scale), Basin Drawings, their supply and demand calculations and all their notes. They will design their rainwater harvesting systems and provide helpful critique to their peers.

Check: Students will craft an explanation of how their engineering design provides shade, conserves water, and serves other stacked functions to mitigate heat and improve infiltration.

Producst: System Designs and *Your Rainwater Harvesting System Worksheet.*

LESSON 10:
COMMUNICATING YOUR ACHIEVEMENTS

Concept: Developing the ability to obtain, evaluate, and communicate information about how a designed rainwater harvesting system meets the criteria and constraints of the Engineering Design Process is a key skill for students.

Activate: Over two class periods, students will develop and deliver a presentation that demonstrates their understanding of the Engineering Design Process and the function of their rainwater harvesting system. Their presentation will include overhead, cross-sectional, and schematic views of the design; an explanation of how it addresses the problem and meets the specified criteria and constraints; and a description of at least one key design decision made to improve functionality or better meet the project requirements.

Students will also construct an evidence-based argument explaining how their design effectively addresses the challenges of providing shade, conserving water, and fulfilling other intended functions to mitigate heat. To conclude, they will reflect on how rainwater harvesting relates to broader regional issues, including increasing heat and aridification in the Southwestern U.S.

Check: A rubric will be used to grade students on their presentations.

Products: Re-designed System Designs and *Your Rainwater Harvesting System Worksheet.*

NEW MEXICO STEM READY! SCIENCE STANDARDS BY TOPIC:

KEY: F = Fully meets the standard as written.
P = Partially meets the standard. Lesson could be expanded to fully meet this standard.
M = Marginally meets the standard. Lesson could be expanded to fully meet this standard.

Middle School

- Physical Sciences
  - Energy
    - MS-PS3-5 - **Construct, use, and present arguments** to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. **CCCs – Energy and Matter** (lesson #) **P**
- Life Sciences
  - Interdependent Relationships in Ecosystems
    - MS-LS2-2 – **Construct an explanation** that predicts patterns of interactions among organisms across multiple ecosystems. **CCCs – Patterns** (lesson #) **M**
    - MS-LS2-5 – **Evaluate** competing design solutions for maintaining biodiversity and ecosystem services. **CCCs – Stability and Change; Influence of Science, Engineering, and Technology on Society and the Natural World; Science Addresses Questions About the Natural and Material World** (lesson #) **P**
- Earth and Space Sciences
  - Earth's Systems
    - 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. **CCCs – Energy and Matter** (lesson #) **P**
  - Weather and Climate
    - MS-ESS2-5 – **Collect data** to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions. **CCCs – Cause and Effect** (lesson #) **P**

        - MS-ESS2-6 – **Develop and use a model** to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. **CCCs – Systems and System Models** (lesson #) **M**
        - MS-ESS3-5 – **Ask questions** to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **CCCs – Stability and Change** (lesson #) **P**
    - Human Impacts
        - 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. **CCCs – Patterns; Influence of Science, Engineering, and Technology on Society and the Natural World** (lesson #) **P**
        - MS-ESS3-3 – **Apply scientific principles** to design a method for monitoring and minimizing a human impact on the environment. **CCCs – Cause and Effect; Influence of Science, Engineering, and Technology on Society and the Natural World** (lesson #) **F**
        - 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. **CCCs – Cause and Effect; Influence of Science, Engineering, and Technology on Society and the Natural World; Science Addresses Questions About the Natural and Material World** (lesson #) **M**
- Engineering, Technology, and Applications of Science
    - Engineering Design
        - 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. **CCCs - Influence of Science, Engineering, and Technology on Society and the Natural World** (lesson #) **F**
        - MS-ETS1-2 – **Evaluate** competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (lesson #) **F**
        - 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 ta new solution to better meet the criteria for success. (lesson #) **F**
        - 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. (lesson #) **F**
- New Mexico Specific Standards
    - Human Impacts
        - MS-ESS3-3 NM - Describe the advantages and disadvantages associated with technologies related to local industries and energy production. **CCCs – Cause and Effect; Systems and System Models** (lesson #) **P**

High School

- Physical Sciences
  - Energy
    - HS-PS3-2 – **Develop and use models** to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associations with the relative positions of particles (objects). **CCCs – Energy and Matter** (lesson #) **P**
- Life Sciences
  - Matter and Energy in Organisms and Ecosystems
    - HS-LS2-5 – **Develop a model** to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. **CCCs – Systems and System Models** (lesson #) **M**
  - Interdependent Relationships in Ecosystems
    - HS-LS2-7 – **Design, evaluate, and refine a solution** for reducing the impacts of human activities on the environment and biodiversity. **CCCs – Stability and Change** (lesson #) **P**
- Earth and Space Sciences
  - Earth's Systems
    - HS-ESS2-2 – **Analyze** geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **CCCs – Stability and Change; Influence of Engineering, Technology, and Science on Society and the Natural World** (lesson #) **F**
    - HS-ESS2-5 – **Plan and conduct an investigation** of the properties of water and its effects on Earth materials and surface processes. **CCCs – Structure and Function** (lesson #) **P**
  - Weather and Climate
    - HS-ESS2-4 – **Use a model to describe** how variations in the flow of energy into and out of Earth's systems result in changes in climate. **CCCs – Cause and Effect** (lesson #) **P**
    - HS-ESS2-5 – **Analyze** geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems. **CCCs – Stability and Change** (lesson #) **F**
  - Human Sustainability
    - HS-ESS3-1 – **Construct an explanation** based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **CCCs – Cause and Effect; Influence of Engineering, Technology, and Science on Society and the Natural World** (lesson #) **P**
    - HS-ESS3-3 – **Create a computational simulation** to illustrate the relationships among the management of natural resources, the sustainability of human populations, and

biodiversity. **CCCs – Stability and Change; Influence of Engineering, Technology, and Science on Society and the Natural World; Science Is a Human Endeavor** (lesson #) **P**
        - HS-ESS3-4 – **Evaluate or refine** a technological solution that reduces impacts of human activities on natural systems. **CCCs – Stability and Change; Influence of Engineering, Technology, and Science on Society and the Natural World** (lesson #) **P**
- Engineering, Technology, and Applications of Science
    - Engineering Design
        - HS-ETS1-1 – **Analyze** a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. (lesson #) **P**
        - HS-ETS1-2 – **Design a solution** to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (lesson #) **F**
        - HS-ETS1-3 – **Evaluate a solution** to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. **CCCs - Influence of Engineering, Technology, and Science on Society and the Natural World** (lesson #) **F**
- New Mexico Specific Standards
    - Interdependent Relationships in Ecosystems
        - HS-LS2-7 NM – Using a local issue in your solution design, **describe and analyze** the advantages and disadvantages of human activities that support the local population such as reclamation projects, building dams, and habitat restoration. **CCCs – Stability and Change** (lesson #) **P**
    - Science and Society
        - HS-SS-2 NM – **Construct an argument** using claims, scientific evidence, and reasoning that helps decision makers with a New Mexico challenge or opportunity as it relates to science. **CCCs – Cause and Effect; Systems and System Models; Scientific Knowledge is Open to Revision in Light of New Evidence; Science Addressed Questions about the Natural and Material World** (lesson #) **F**